HOUSE ORGAN OF Q-ALLOYS "To Be Sure" GENERAL ALLOYS COMPANY

ALLOY PROGRESS

EDITED BY H. H. Harris PRESIDENT

Bright Spot in Metal Progress

ENTIRELY ABOUT HEAT & CORROSION RESISTANT ALLOY CASTINGS

Vol. 4 No. 3

AN INSPIRATION TO BETTER ALLOYS

LAST week I sold* my "White Elephant," Hirondelle de Monte Carlo, Royal Yacht of the Prince of Monaco. When I found her she was truly a "Lady in distress." But chivalry alone, nor yet profit did not prompt my purchase. I really bought her to satisfy my hunger for sincerity in men and metals at a time when the depression was squeezing to light the infirmities and iniquities of men, making inferiority a standard and mediocrity a goal in that mire of "Depression."

YOU'VE felt that hunger for *real things*, too. Possibly you've turned for inspiration to the fine achievements of real men, when the pettiness of lesser men, the frailty of "friendships" was depressing. To me, after pleading with economic illiterates at a Code meeting, or resisting the temptation to take an order at a chiseler's price, (and make a profit by producing competitive quality), a visit aboard Hirondelle brought solace. I felt a kinship with her designers, builders and navigators, for they knew no compromise with character or quality.

RARELY, in human experience are Knowledge, Sincerity, and Means—superlative KNOWLEDGE—SINCERITY, and MEANS, concentrated in a single objective without compromise with men or money. Hirondelle was such a rarity. J. P. Morgan's "Corsair," almost her twin sister, is another.

HIRONDELLE is a supreme embodiment of science and engineering. Marine architecture was for centuries the only engineering worthy of the name. Structures on land have only to be erected to defy gravity, while ships fight the ocean's wrath, lead a life of torturous test—building men and nations. The engineer who has not studied ships is poorer in logic and inspiration, is an amateur at *design compromise*, the "Philosophy of Mechanics" underlying achievement.

HIRONDELLE'S building took 2,650,000 man-hours, from teakwood loggers in Indian swamps, flax beaters in Ireland, hemp pullers in Manila. Each working on a "Royal Command" to excel himself. From her corrosion resistant alloy plates, to her hydraulic steering gear and costly hydrographic equipment, she was built with loving care. Teak cut "in the full moon," for tree sap, like the tides and Homo Sapiens, is elevated by the full moon.

I COULDN'T afford to operate Hirondelle — just bought her like a painting or a good tool, for the inspiration of ownership. Some may not understand that inner satisfaction that comes from association with exalted conception brought to being through superb craftsmanship. One seldom loses buying the proven product of sincere men.

I HAVEN'T time for Hirondelle — my first love, Q-ALLOYS, is too possessive—but I did place her in understanding hands. She will go into service between U.S. and South American ports in June. I hope to be aboard with my plane. Give Hirondelle credit for inspiring better alloys, and call me a sentimental sap if you wish.

H. H. Harris

P.S.
If you like sharing my dream, here's some more Hirondelle "copy" I wrote under her spell:

MONTE CARLO, smiling and beautiful seat of the Goddess of Chance, the social sporting capital of Europe, beckons from the Mediterranean, offering Romance, Wealth, Luxury, and Adventure.

NESTLED to her turquoise bosom, restlessly riding anchor, lies Hirondelle (the Swallow), most famous yacht in the world, the restless steed of a fearless, questing soul, Albert First, Prince de Monaco, Prince of Navigators, Noble of Neptune's Court, Author Extraordinary, beloved scientist.

OUR Prince spent the greater part of his life at sea, winning renown as a scientist, exploring the depths of the Seven Seas, while the world's great and glamorous flocked to his incandescent capital to study the laws of chance at roulette and baccarat, where Phi Beta Kappa comes hard. The fruits of his salty vineyard include 44 volumes of Oceanography, the finest Marine Museum in the world, at Monte Carlo, and a number of enchanting books. If you are seagoing you've probably read: "Scientific Trips Upon Yacht Hirondelle"—"The Career of One Navigator"—"Hirondelle Under The Stars."

PRINCE ALBERT'S ships were the ultimate in seaworthiness, luxury and mechanical ingenuity—plans drawn, hulls fashioned, with loving care in the sincerity of superb craftsmanship. Of them all, Hirondelle, the lovely Swallow, graceful as her name, majestic as her royal lineage, luxurious as the forsaken palace, is the noblest.

(Continued on last page)

*At a profit.

HIRONDELLE de Monte Carlo Royal Yacht of the Prince of Monaco

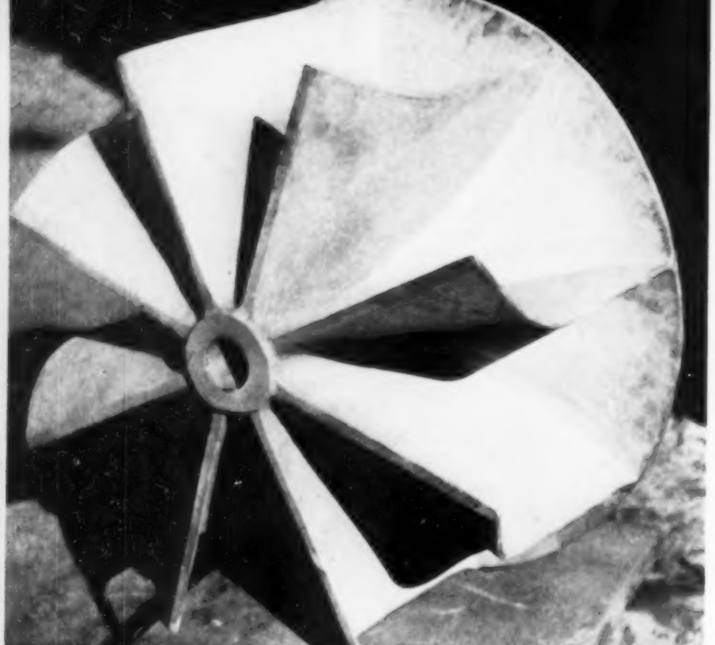

The Palace of the Prince d'Monaco, Monte Carlo


Musée Océanographique - Hirondelle in Harbour


Casino, Monte Carlo

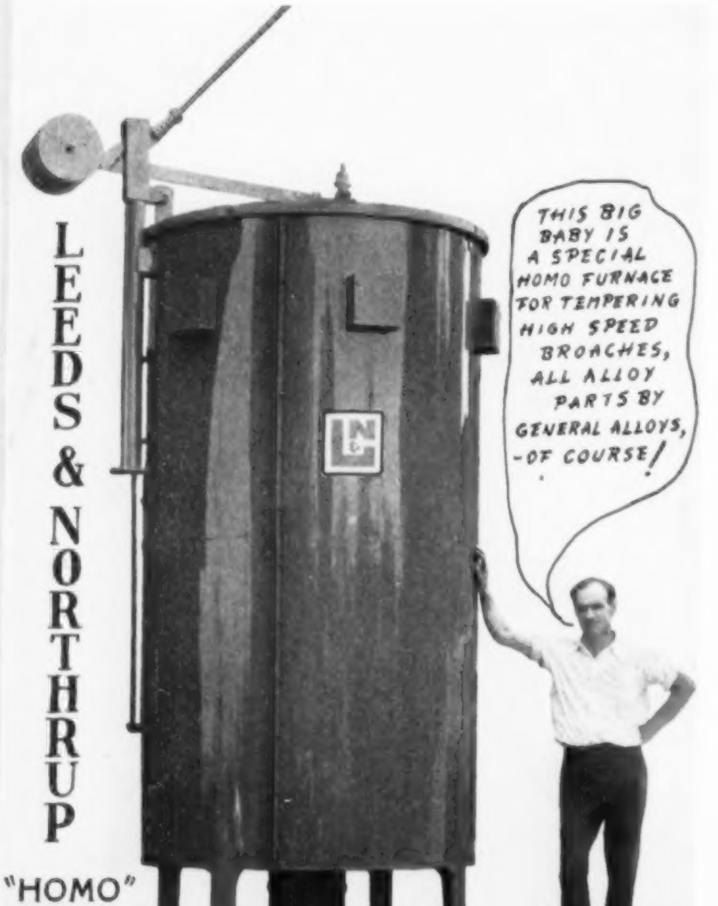

Stateroom occupied by German Kaiser on world cruise


Stateroom of the Prince of Monaco



"General Alloys Company has built more High Temperature Convection Fans accidentally than the esteemed contemporaries have on purpose" remarked a G.A. Engineer, and he probably made a conservative statement. We have been making them for seventeen

years. From hundreds of small fans in L. & N furnaces to fans for carburizers and six foot diameter door mounted fans. And speaking of screws and propellers, here's a nice internal spiral retort twelve feet long.



IN A weak moment, you've probably dropped a nickel in one of those "Push the button and blame yourself" multi-tunious phonographs. Most colored cooks won't work in a Greek restaurant without one. Now they're turning out fifty a day in Wurlitzer's fine factory at Tonnawanda, and the testing room overture is the perfect musical score for Dante's Inferno. Well, I had the Granddaddy of all those things up in the air. I speak of Rudolph Wurlitzer, head of biggest house in music, who recently flew with me while shooting some pictures over Cincinnati. Here's one of them. Mr. Wurlitzer also makes Harps, Pianos and Organs, as well as carousal music boxes. He has one of the finest collections of etchings and of Violins in the world, and is the outstanding American Authority on Violins. He doesn't use alloy. If he did, it would be the best.

GO UP in the air a thousand feet, around Boston, and the air is warm and balmy, 20 degrees warmer than on the ground. This condition is recurrent, and is blamed on the Gulf stream moving in on us, "trade winds running coastal," etc. Anyhow, we've left our brass monkey out all winter, and the neighbor's hired girl is burning forget-me-nots and love lyrics on our snow-shovel. It's *that* springy.

I LOST a hundred dollar bet, which I would have paid a thousand dollars to win. I bet on the loyalty of an employee, overlooking a previous disloyalty, a bad financial record. I thought I had won that bet when the white feather showed up and licked both of us. General Alloys marches on.

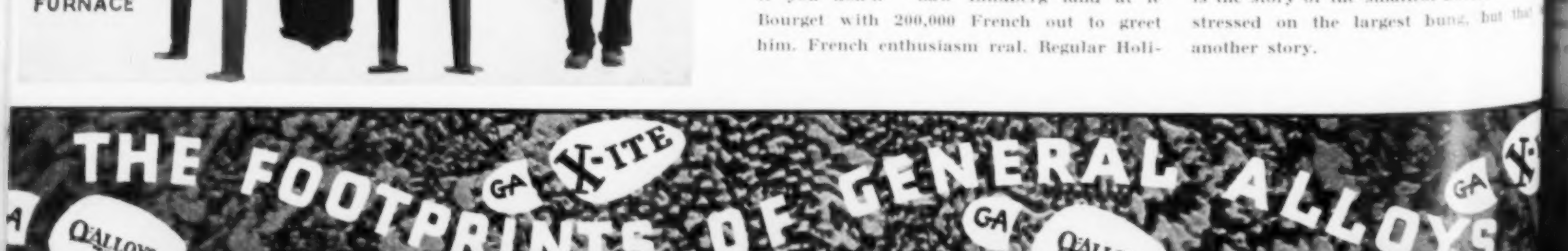
LOOKING over Vol. I, No. 1 of "Alloy Arguments" an eight-page house organ we used to run in *Forging and Heat Treating*. I get a kick from reading what I wrote on return from a trip to Europe in 1927. See if you don't. "Saw Lindberg land at le Bourget with 200,000 French out to greet him. French enthusiasm real. Regular Holi-

Fisher Body Plant, Cleveland, Wher Sitz-Strike Started

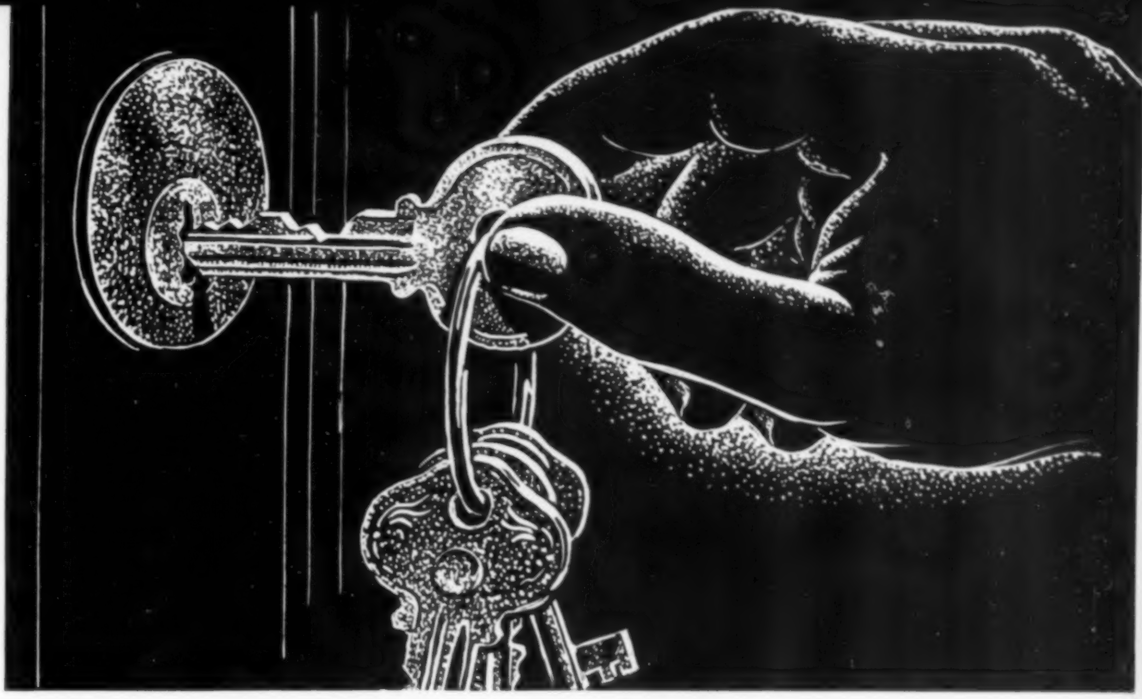
day in Paris. Lindy has Wales beat ... National Sales Manager. Won new hat fr... French bartender, bet against a package ... Camels on Lindberg's arrival." Of Germ... I wrote "Germany is thoroughly tooling ... financing her industrials for a comeback th... will startle the world." *The world has be... well startled.* Of Italy I wrote "Italy, ne... to Germany, is most active . . . . . more we... trained competent young executives than an... European country. Italians inspire con... dence. *Bet on Italy.*" The League of N... tions bet against Italy.

IN CASE you go in for any of those lo... broaches, you'll see the real need for th... new HOMO Tempering Furnace on your le... You've got to hand it to that Leeds & Nort... rup outfit. No one ever said they were n... "Tops" for quality, or accused them o... building any compromise stuff anytime. A... through the depression they stuck to the... standard specifications of General Allo... castings, and all of them designed for maxi... mum life and made from metal patter... costing more than "necessary." No Le... & Northrup customer was a "guinea pig" fo... a "cheap" alloy peddler. While L & N fu... naces carry a One Year Guarantee, they'... alloyed for five to ten years. *(L & N ... "save" 5c lb. and give their customers "... year alloy.")*

AN "English Maiden Lady of unquestion... social insight," interested in the w... of Elizabeth Fry in Newgate Prison, Lond... wrote in her journal under date of Octob... 11, 1818, "Prostitutes are poor needlewom... else they could ply the needle and be spa... a life of shame." She writes of indus... and understanding as essential to self re... spect. This prompts me to observe that... commercial *fille de joy*, the salesman w... sells on price is just a "poor needlewoman." Had he the industry and understanding ... make good alloy, or to serve his intend... customer to the latter's profit he would ... viously not be what he is. Of course th... is the story of the smallest barrel that ... stressed on the largest bung, but that ... another story.



BLIC be Damned" must be the slogan f many railroads, and the same general ness has seeped through the premises. news stands have stopped selling the rs' *Digest*, offer a lot of trash "Di-" Is the profit motive in periodicals so that the risk of heaping further indig- on the traveling public can be ignored endors in railway stations, when the ds certainly need good reading matter e the public mind off the rotten serv- Waiting till ten o'clock for dinner on oston and Albany, for instance.



Corrosion Resistant Castings Are Our Specialty

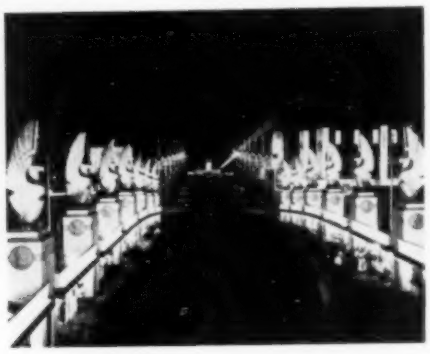
EMINDS me of when the Blackstone Hotel in Chicago had a row over "More cut" the telephone company and locked the lic out of the phone booths. I gave it go-by. Many others did too. Shortly rward it closed its doors.

EN John L. Lewis can't tell the public to go to hell, and get away with it. y the best hotel in America twenty ago, the Blackstone has re-opened, and regain its place.

EAKING of the *Reader's Digest*, I have on my desk a January copy, and have ad for the fifth time, "Unfinished Busi-," by Lincoln Steffens. If you have a cut out those three pages and frame for him. "I teach my child and I tell r children of all ages — pre-school, in l, in college, and out: *That nothing is finally and right. That nothing is n, positively and completely* . . . . there verything for youth to take over."

The Key to Repeat Alloy Orders in Detroit, and in industries everywhere where PRODUCTION DEPENDS ON ALLOY CASTINGS, is DEPENDABILITY.

DEPENDABLE ENGINEERING, insuring proper design.
DEPENDABLE MANUFACTURING, insuring mechanical and metallurgical DEPENDABILITY.
DEPENDABLE DELIVERIES, more a matter of pattern equipment, facilities, and *daily production of several analyses*, than geographical location.
DEPENDABLE SERVICE for the life of the casting.
DEPENDABLE LOCAL REPRESENTATIVE, established and respected in your community with the experience to make his recommendations RESPECTED, who is there *when you want him*.
FINANCIAL RESPONSIBILITY AND DEPENDABILITY OF THE MANUFACTURER AND REPRESENTATIVE. There is one key to REPEAT ORDERS, that key is DEPENDABILITY.



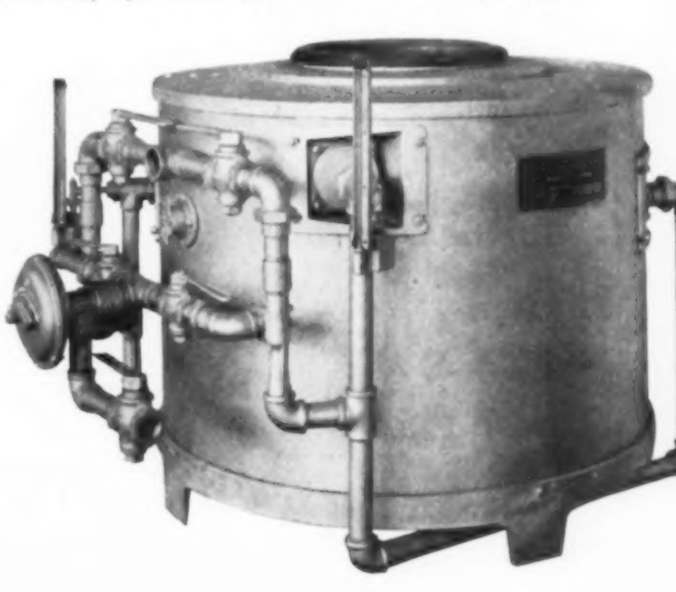
Mr. G. B. Berlein, Hardener at Lindberg Steel Treating Company, Chicago, sent in some remarkable photographs of his own making. The excellent night shot of the Great Lakes Exposition in Cleveland, above, is his. Congratulations, Mr. Berlein!

IT'S good to know that like the new automobile which becomes "Second Hand" with the down payment, styles and machines, modes and furnaces and alloy mechanisms are obsolete long before they wear out. Any pusher furnace not equipt with hinged trays is obsolete. The new furnaces will have four, or five rails and the tray weights will be cut about 50%.

THE savings on alloy trays will pay for the extra rail cost about six times over in direct alloy cost without considering the tons less material heated each day. If you buy any pusher furnace without consulting your nearest "G" man, you're just walking into avoidable expense with your eyes open.

NEW SURFACE COMBUSTION POT FURNACES

THERE is probably no installation where a good furnace will pay for itself so quickly as on cyanide and lead hardening. Good combustion conditions prolong pot life, save costly breakdowns. Scores of Surface Combustion furnaces, equipt with Q-Alloy pots are serving large and small industries everywhere, and Surface Combustion Engineers are constantly improving these simple pot furnaces, as well as the more complex types.



(Continued from page 1)

"ALBERT has covered more miles of blue water in his sleep," writes Lord Athlumney, "than many a brass-bound Admiral under orders. Hirondelle's log ranks with the greatest of all time, as does the ship herself."

THE German Kaiser chartered Hirondelle for his personal use on the recommendation of the Imperial Germany Navy as "The most sea-worthy and appropriate yacht afloat." Later, when she served in the French Navy during the War, his orders to the subs were "Sink Hirondelle in shoal water, for possible re-flotation," but the nearest she came to disaster was when her French Commandant found Wilhelm's house-flag in her chart locker and had a litter of calico kittens. (I have that flag.)

ROYALTY, the elite of international society, sachems of science, have walked her holi-stoned decks, inspecting Prince Albert's trophies of the deep, posting him on Europe's intrigue, while his divers plumbed the depths of the Seven Seas, and booming cannon welcomed Hirondelle to the ports of the world.

COMMANDING admiration, inspiring imagination sinuously graceful vitally Regal, Hirondelle grips one; first gently, then engulfing in that enveloping aura of romance that is a part of her. A glamorous living legend of the Seven Seas echoing whispers of royal intrigue, tinkling laughter, affairs d'amour, rustling silks and crackling oilskins, clinking glasses, old lace in candlelight, golden curls on silken pillows.

IF EVER there was a spot where man could commune with the spirit of high adventure, count the crystal beads of childish dreams, and fan them from gentle musings

into vibrant reality, it is on the quart
of Hirondelle, as you turn the kaleido
of her living log. Even the dull-witted
speculated romantically and convincingly
the secret stairway leading from the Prin
stateroom to the guest suite above. F
might outrun their fancy.

MODERN from the remote-controlled
in her five water-tight bulkheads,
double-bottom, to her rubber-mounted
liaries, and sixty carcass cold room wit
E. refrigeration and ice plant. Luxu
from her royal suite, wine holds and
dry to her 374 feet of teak-paneled
teak-covered steel decks and deckho
Seaworthy from her lines to her log

her twin 1500 horsepower engines drive
17 knots, with fuel for 7000 miles.
makes her own fresh water.

I will send an 8x10 photo of Hirondelle
any boy from six to ninety if he, or
father, is a member of A.S.M. If your
pany uses alloy castings, or makes or
heat treating equipment, write for one
your letterhead, or, if you prefer one of C
cinnati or Statue of Liberty.

Two upper cuts, Hirondelle in drydock
Boston. Bottom, Captain John N. W
U.S.N.R., Skipper.

EFFECT OF WATER VAPOR ON HOT METAL

By A. G. Hotchkiss
Industrial Heating Engineering Dept.
General Electric Co., Schenectady

I SHOULD LIKE to consider the question of water vapor in furnace atmosphere in connection with the problem of retaining bright surfaces on metal during and after heat treatment in furnaces of a type that permits maintaining the atmosphere independently of the source of heat. Such furnaces are the ones heated with electrical resistors, or those with a muffle or a closed retort, no matter how it is heated.

Generally, when gases used for protective atmospheres are discussed, we talk of hydrogen, nitrogen, the carbon oxides CO and CO_2, or mixtures of these four, as would be determined by ordinary gas analysis. Water vapor, which always plays a very important part, is easily and all too often completely overlooked. An exception to this statement might be the bright annealing of copper, where 100% water vapor is used as the atmosphere in the form of superheated steam, the hot copper being cooled by quenching in water direct from the steam chamber. From this specific condition we must decrease the water vapor to fairly low amounts for practically all other ferrous and non-ferrous metals and alloys.

There have been considerable theoretical data published in the last few years concerning the equilibrium of gases and combinations of gases in contact with steel at various temperatures. These data generally are very theoretical, technical, and not readily applied to actual furnace atmospheres encountered in practice. A. L. Marshall, of General Electric Research Laboratory, however, substantiated the physico-chemical theory with some experiments on low carbon steel, and showed that under ideal laboratory conditions the theoretical results hold true to a fairly close degree (see *Transactions*, ⊕, July 1934, p. 605).

Those experiments show that the amount of water vapor that can be present without blueing steel at any temperature up to 1200° F. is a function of the hydrogen present. Action below 600° F. is too slow to be a matter of concern in this respect, and it can be seen, therefore, from the curve sheet on the next page that a gas containing 95% H_2 and 5% H_2O (ratio $H_2O:H_2 = 0.05$, represented by the vertical ordinate *a-a'*) would not oxidize bright steel at any temperature and in that sense would be "neutral" to bright steel. As a matter of fact, any iron oxide on it would tend to be reduced.

The curve marked "H_2O : H ratios for equilibrium" represents the combinations of these two gases that are in equilibrium with iron at the respective temperatures, that is, would

neither oxidize iron or reduce any oxide which happened to be present. Analyses and temperatures which plot well to the left of this curve would reduce scale, the more vigorously the further away from the equilibrium line; in the same way, bright steel would be oxidized under conditions plotted below and to the right of this curve (neglecting for the time being the effect of the CO_2 : CO curve).

In actual practice, however, the actual atmosphere cannot be regarded as a mixture of pure hydrogen and water vapor, even though the gas is carefully prepared, for the atmosphere is in contact with oily steel, alloy retorts, various types of brick and insulation, and all of these can change conditions considerably. We should, therefore, work on the reducing side of this curve. Assume a gas at 1200° F. with 15% H_2 and 3.7% H_2O (ratio of 0.25). This point plots at b' and is well within the reducing range; however, when the temperature drops to 975° F., we theoretically cross the equilibrium curve and enter the oxidizing range. If the atmosphere consisted only of H_2 and H_2O in these proportions, then it would appear to be impossible to cool below 975° F. without oxidation taking place.

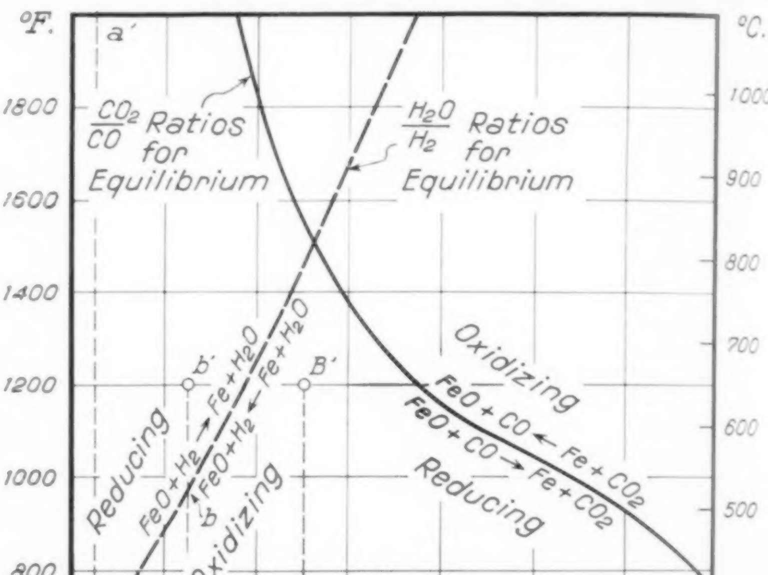
If, however, we have a complex gas containing also CO and CO_2, such as obtained from the partial combustion of hydrocarbon gases and which method is in general use today, the situation changes. The theoretical equilibrium curve for iron, CO and CO_2 has the opposite slope, crossing that of Fe, H_2O and H_2 at about 1500° F. Therefore, if we have, say, 5% CO_2 and 10% CO in the above gas along with the hydrogen and H_2O, the ratio of the carbon gases (0.50, plotted as B'-B) shows it to be quite strongly reducing and increasingly so as the temperature decreases.

It is possible, therefore, with the complex gas to cool steel down through this critical range below 1000° F. without oxidation because the reducing effect of the CO_2:CO equilibrium overcomes the oxidizing effect of the H_2O : H_2 combination.

This explanation of conditions in complex atmospheres may strike some students of the problem as being somewhat too rough and ready for accuracy. Theoretically, the situation is governed by the so-called water gas reaction

$$CO_2 + H_2 \rightleftarrows CO + H_2O$$

and only a very low percentage of moisture is allowable at, say, 750° F. This calculated limit is far below the point where, in actual practice, we find we can operate — doubtless owing to



Theoretical Equilibrium Relations Between Iron, Hydrogen and Steam and Between Iron, CO and CO_2 at Heat Treating Temperatures

the various rates at which the many possible reactions may proceed. The whole problem involves several unknowns. It is, therefore, a trial and error method that gives the answer in practice, although theoretical data give one the general direction in which to proceed.

We have found that although we could, in the laboratory, bright anneal with partly burned fuel gases containing 10% H_2 and saturated with moisture at 83° F. (containing 3.7% H_2O, as shown by the humidity table on page 378), in actual practice this gas is too near the oxidizing range. To avoid trouble the hydrogen should be increased to 15 to 18% or the water vapor decreased to 2.5% (saturated at 70° F.) or both — that is, reduce the H_2O : H_2 ratio to 0.25 or less. The amount of hydrogen

in such partially burned gas may be increased by decreasing the air going to the burner, which will automatically decrease the CO_2 : CO ratio (increase the relative amount of carbon monoxide) thus throwing the whole system further on the reducing side of both equilibrium curves.

Dew Points

It might be well to pause here and refresh our memory about dew points. Some figures showing the amount of water vapor that can be held in air, or any other gases that do not react with it, are contained in the table on page 378. It is easiest explained by reference to summer atmospheres. If the thermometer reads 80° F. the most water vapor it can hold is 11.0 grains per cu.ft., or 3.43% by volume. If the temperature should fall, it would rain, and even if it doesn't rain, ample moisture will condense on the surface of a pitcher of ice water. But if the observer were somewhere in the dust bowl, the temperature the same, and the relative humidity were only 10%, then the atmosphere would contain 0.34% H_2O by volume and no moisture would condense on a cold water bottle. In fact, the air would have to cool to about 19° F. before any water would condense out as fog — it would be snow or frost at that low a temperature.

Or put it another way — if the prepared gas is saturated with water at 130° F. (containing 15.2% H_2O) and it is desired to dry the gas, one way would be to cool it, whereupon the gas becomes supersaturated and precipitates out as liquid water. Cooling water can frequently be had in sufficient volume at 70° F., and this will bring the water vapor down to 2.44%. Further cooling by a commercial refrigerant is effective down to 40° F., whereupon the gas contains only 0.82% moisture. Below that temperature the condensate will freeze on the coils. It is usually desirable to use refrigeration when the condenser water temperature is above 70 to 75° F. When "bone dry" gas is necessary and dew points of —20 to —50° F. are desired, chemical driers employing activated alumina or silica gel are used with good results.

Drying can also be done by compression, and this is useful in the many cases where it becomes advantageous to raise the pressure of the prepared gas for storage purpose or ease of distribution. Raising the pressure of a gas "squeezes" out the water vapor. The table also gives some information as to this. Assume a gas at normal pressure and saturated at 80° F.; it contains 3.43% water. It is interesting to note that this gas compressed to 14 lb. gage and then cooled to 80° F. would condense out about half of its water and would then contain 1.72% H_2O. This corresponds to saturation at 60° F. Compression to 60-lb. gage and re-cooling the compressed gas to 80° F. would dry it to the equivalent of 32° F. saturation. A gas from a high pressure tank at 1000 lb. would be practically dry, or saturated at approximately —26° F.

Resuming now with the effect of this water vapor, it is interesting to note that in commer-

Three Bell-Type Electric Furnaces (With Ten Bases) For Annealing Coiled Steel Strip in Plant of Sharon Steel Corp. Note small flames at top of two bases at lower right, where exhaust of protective atmosphere is burning

cial heat treating operations, dew points have been taken of gases from a batch-type furnace chamber indicating a saturation at 95° F. — that is to say, 5.5% H_2O. Even if this gas contained 15% H_2, the $H_2O : H_2$ ratio of 0.37 is quite near the equilibrium curve at annealing temperatures, yet the steel came out bright from a 30-hr. cooling cycle by virtue of the large amount of CO in the atmosphere.

The effect of *time* on the rate of reaction of oxidation equilibria is well shown in comparing the batch-type furnace just mentioned with the rapid cooling obtained in the continuous furnace. In one instance bright steel parts came from a copper brazing furnace although the atmosphere, which was the product of partial combustion of natural gas, contained approximately 15% H_2 and 8.0% H_2O (or saturation at 107° F.), that is, a ratio of 0.53.

This brings us to the effect on steel at higher temperatures, such as 2100° F. for copper brazing. We note from the curve that a greater amount of water vapor can be tolerated at elevated temperatures and still maintain a reducing condition. Equilibriums between CO_2, CO, H_2 and H_2O are reached rather rapidly at these temperatures; however, it is such that considerable water vapor is formed and it is possible with a gas containing 3.2% CO_2, 11% CO, 20% H_2 and 12% H_2O (or saturation at 120° F.) to have a sufficiently reducing atmosphere so that the steel is wetted with the copper, although it would be impossible to cool the brazed part *in* this atmosphere, even at a fairly rapid rate, without considerable oxidation of the steel. The copper, however, would remain bright.

Dr. Marshall's experiments have also brought out that various combinations of these gases far out of equilibrium would etch a steel sheet, by its catalytic effect on the chemical reaction $2CO \rightarrow CO_2 + C$. This caused the bright surface of cold-rolled steel to take on a matte finish resembling a pickled surface; in extreme cases considerable carbon was deposited.

Water Vapor in Air or Gas

Dew Point °F.	Gage Pressure Equivalent*	Weight of H_2O Vapor Grains/Cu.Ft.	Weight of H_2O Vapor Lb./Cu.Ft.	H_2O Vapor, % by Volume
−28	1075	0.147	0.000021	0.0367
−24	915	0.175	0.000025	0.0441
−20	725	0.217	0.000031	0.0552
−16	600	0.266	0.000038	0.0682
−12	500	0.315	0.000045	0.0817
− 8	400	0.385	0.000055	0.1005
− 4	340	0.455	0.000065	0.1195
0	285	0.540	0.000077	0.143
4	235	0.643	0.000092	0.173
8	195	0.770	0.000110	0.208
12	160	0.910	0.000130	0.248
16	135	1.080	0.000154	0.279
20	113	1.275	0.000182	0.353
24	97	1.510	0.000215	0.420
28	76	1.785	0.000255	0.502
32	60	2.10	0.000300	0.597
40	43	2.83	0.000405	0.818
50	25	4.06	0.000580	1.195
60	14	5.73	0.000820	1.72
70	5	7.98	0.00114	2.44
80	0	11.00	0.00157	3.43
90	.	14.85	0.00212	4.72
100	.	19.70	0.00283	6.4
110	.	26.40	0.00377	8.68
120	.	34.50	0.00493	11.55
130	.	44.60	0.00637	15.20

*Gas compressed and condensate removed at 80° F. All measurements based on atmospheric pressure.

When the equilibrium was restored to near theoretical value by addition of water vapor, all etching stopped. A gas composed of 4.8% CO_2, 10% CO, 19% H_2, remainder N_2, and a dew point of 5° F. (0.18% H_2O) caused etching. This same gas with enough water vapor added to raise the dew point to 32° F. (0.60% H_2O) produced perfectly bright steel at 1200° F. and below. The dew point could also be increased to any value up to 85° F. with this gas composition and no oxidation would result at or below annealing temperatures.

The above gas composition when used at dew points neutral to steel will change the bright surface of Monel at 1700° F., to a clean but dull gray color, but when the water vapor is reduced to very low values, such as dew points of −25° F. or below, the bright polished surface remains unaltered, equaling results obtained by annealing in an atmosphere of dissociated NH_3, which is practically free from water vapor.

It is a well-known fact that iron oxide reduced to free iron by hydrogen forms water vapor in the process. If, for example, hot-rolled steel sheet covered with mill scale is being annealed or normalized in a reducing atmosphere containing hydrogen, such as mentioned above, the water vapor would rapidly increase to the point where equilibrium would be reached and no more oxide would be reduced.

It therefore becomes necessary under such conditions to flush out the water vapor and replace the used up hydrogen to maintain a reducing atmosphere and prevent re-oxidation during the cooling cycle.

Analysis for Water Vapor

The difficulties encountered in measuring the water vapor contained in a gas account, to a great extent, for the lack of attention given this important constituent in furnace atmospheres. Considerable effort has been expended along this line by the General Electric Co. and we have finally devised a simple "dew meter" which gives direct visual indication of the dew point. It consists of a small metal box with a polished metal mirror set in one side. This is visible through a glass window. The gas being tested is allowed to flow through the box while the mirror is slowly cooled by a jet of cold gas, expanding from a cylinder of compressed air or carbon dioxide. A thermocouple on the mirror permits a direct temperature reading, at the instant water condenses upon the mirror. The indication is very definite and the reading accurate. This instrument has been used for dew points as low as −60° F. This makes a convenient, practical and portable instrument for water vapor determination.

In conclusion, may I remind you that when difficulties arise with furnace atmospheres and analyses are being checked, do not forget the water vapor.

CAUSE OF FLAKES IN STEEL INGOTS

By Kôtarô Honda and Tokutarô Hirone

Abstract from Science Reports, December 1936, p. 713
Tôhoku Imperial University

INTERNAL PRESSURE of hydrogen is the cause of flakes, in the opinion of German investigators recently published. (See METAL PROGRESS, July 1935, p. 51, and September 1935, p. 63.) Experiments show that this pressure rapidly increases with falling temperature and reaches a value greater than the tensile strength of the material. It is, however, to be remarked that the theoretical deductions are valid only when the gas in a cavity and the gas absorbed in the metallic walls of that cavity are in equilibrium at a given temperature, and do not apply to the case of internal pressure caused by the gas atoms or molecules within the iron crystal lattice.

Hence in order to investigate the effect of dissolved hydrogen gas on the formation of flakes in steel ingots, it is necessary to assume that minute cavities are present in steel ingots, into which the dissolved gas is evolved during cooling and causes the increase of pressure within them, thus resulting in the formation of flakes. Under these circumstances, it is shown by available experimental evidence and mathematical deductions that in the first approximation, the quantity of the gas dissolved in steel does not change by cooling. This is evident, because when the volume of a cavity is extremely small, the liberation of a very small quantity of the gas into the cavity produces a pressure which is sufficient to prevent a further liberation of the gas into that cavity. It is also deduced that as the temperature falls from a certain sufficiently high temperature to a very low temperature, the gas pressure within such a minute cavity increases at first slowly, then very rapidly, and after reaching a maximum it diminishes linearly, vanishing at the absolute zero of temperature.

These formulas are capable of numerical computation. On the assumption that a body of steel just below its solidification temperature is saturated with 0.0023% of hydrogen, the pressure is inconsiderable until 500° C. (950° F.) is reached, but then rises rapidly to a peak of about 500,000 psi. at 250° C. (500° F.) and then decreases linearly to nil at absolute zero. This is for a cavity of 0.0135 cu.mm. However, for a spherical cavity ten times as large, the internal pressure is at a maximum of less than 60,000 psi. From these figures it will be seen how great is the effect of the volume of the cavity on the pressure within it. The temperature of maximum pressure coincides with the temperature of flake formation as determined by interrupted cooling experiments. (See Musatti and Reggiori, **Metal Progress**, July 1936, p. 51.)

In a deep-seated cavity the tangential stress at the spherical surface is one half the gas pressure, so the stress in small cavities is sufficient to break its surface. If the form of the cavity is not spherical, the value of the tangential stress varies from point to point and differs more or less from that given above. So, in the case of a flat cavity, the tangential or breaking stress should be very large

(Continued on page 434)

DIAGNOSIS OF METAL TROUBLES IN INDUSTRY

Part 1—Forging

By J. L. Burns and V. Brown
Metallurgical Dept., Republic Steel Corp.
Chicago District

"*Why did it break*" or "Why did it wear out so soon," are questions which often confront the metallurgist. Upon a correct answer depends the future success of the part or structure under consideration. Incorrect diagnosis of the trouble, like incorrect diagnosis of human ailments, may lead to unfortunate results — the trouble may not be corrected at all, or it may be corrected by resorting to materials, processes and inspection standards that are unnecessarily expensive.

Many troubles have so long been recognized and are of such common occurrence that one might think they could never happen again;

SURFACE LAPS ON FORGING

The photomicrograph Fig. 1, at 40 diameters, shows the decarburization and oxide stringer resulting from surface lapping . . . . Figure 2 is a macrograph, actual size, and shows lapping on a pickled forging. These laps occur for the most part at the fillets on this forging. Other laps, on chisels, are shown in Fig. 8, page 382.

Fig. 1

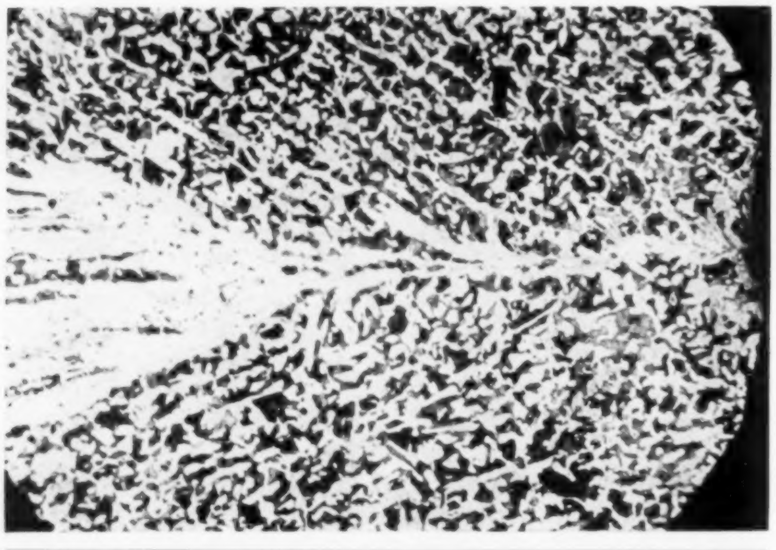


Fig. 2

nevertheless, these troubles are encountered almost every day in long established manufacturing plants and frequently are not recognized by experienced men. We still find heat treated parts being drawn at too low a temperature in order to meet a hardness test on a badly decarburized surface. We often find grinding cracks in plants where it is said that grinding cracks have never occurred. And in spite of the fact that our ancestors have been notching materials of all kinds for thousands of years in order to break them easily, we still find designers and machine shops putting dangerous notches into highly stressed metal products!

The illustrations on these six pages and their descriptions are intended to show some of the troubles that have come to the attention of only one laboratory of one steel producer, and are presented with the hope that they may be useful to others who have to deal with similar problems, or will enable metallurgists who may run into such troubles to recognize them and then to take the obvious steps to correct them.

R. S. ARCHER

Fig. 4

Wrinkling during forging, caused by improper reduction, is shown in various stages of the operation in Fig. 3, below, at one-half actual size . . . . The photomicrograph above shows the sealed-in oxide stringer resembling a seam which results from the lapping effect attending this wrinkling. (Magnification 50 diameters; nital etch.)

IMPROPER DIE DESIGN

Fig. 3

Fig. 5

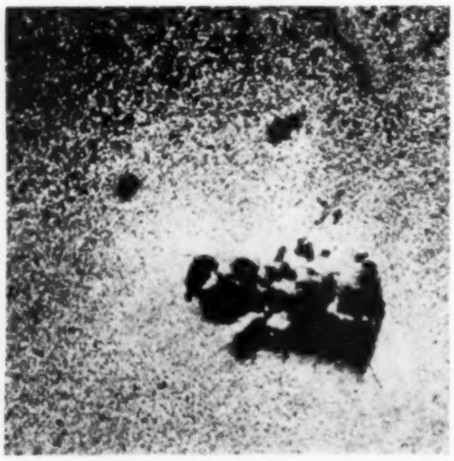
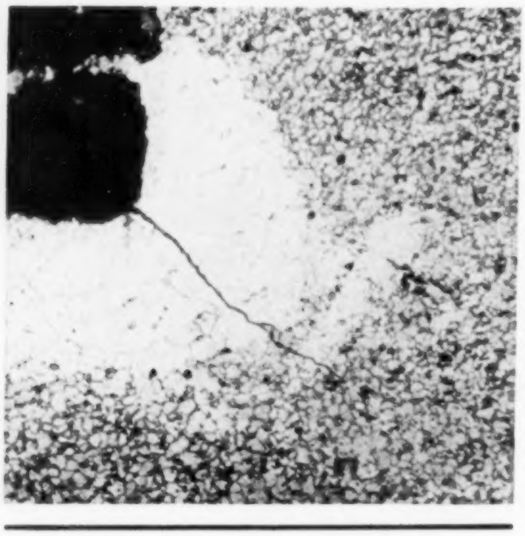


Fig. 6 (25x)

Fig. 7 (75x)



SCALE TROUBLES

Scale, when allowed to be hammered into the surface of parts during forging, will cause pits which are exceedingly hard to clean up afterward. If permitted to remain on highly stressed tools such as chisels, cracks will start in the decarburized area attending the pits, as shown in Fig. 6 and 7, and progress through the tool ultimately causing complete failure. Scale should be kept from collecting in dies by some method such as an air stream.

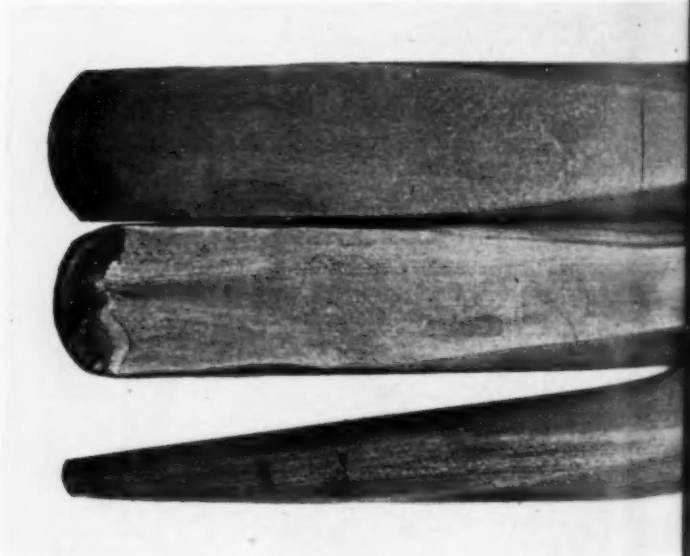


Figure 8 shows laps caused by improper die design; they serve as notches and definitely lower the impact value of the steel and thus the useful life of a part.

BURNED SURFACE
OR
"CHICKEN WIRE"

Heating a thin section too rapidly, prior to finish forging, burned the surface with the resultant large network of oxide (Fig. 10; magnified 50 diameters; nital etch) . . . . . Subsequent normalizing refined the austenite grain size, as shown in Fig. 11, but the enlarged oxide network remained (near the surface) giving the "chicken wire" appearance on pickling shown actual size in the macrograph, Fig. 9 (difficult to photograph satisfactorily).

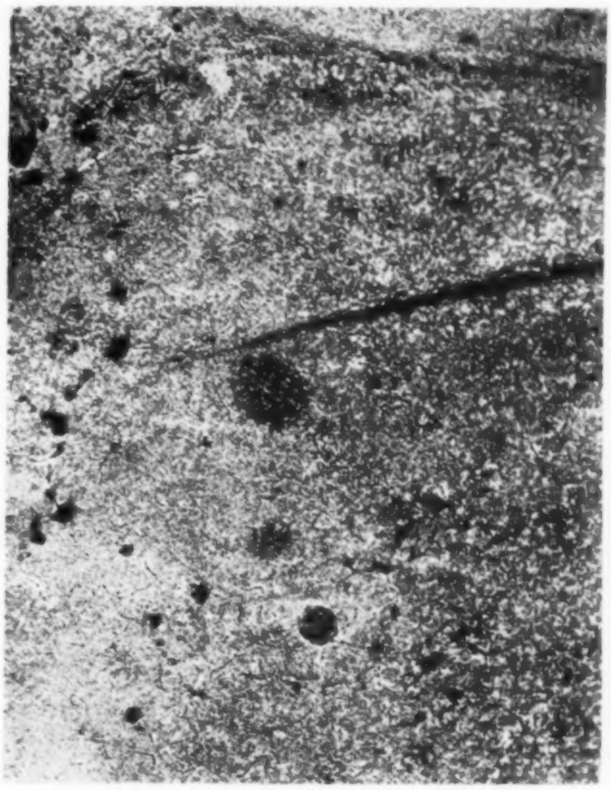


Fig. 9; Pickled Surface, Full Size

Fig. 10 (50x)

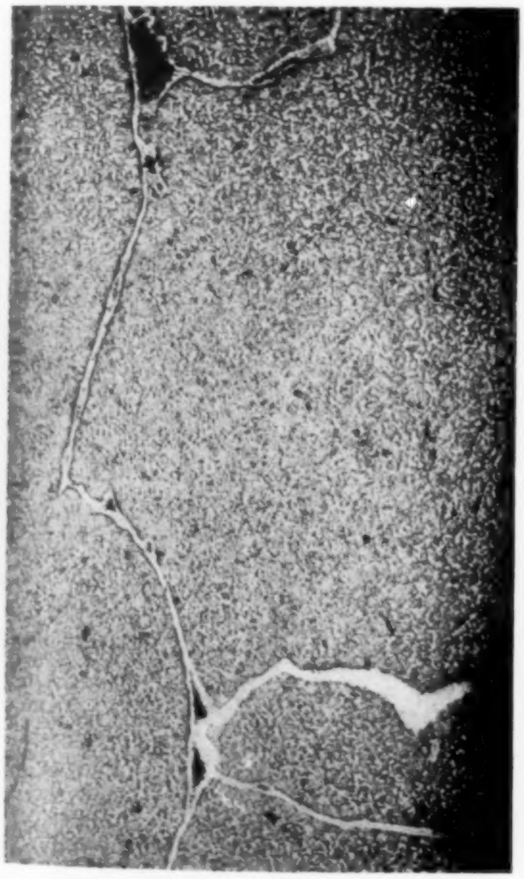
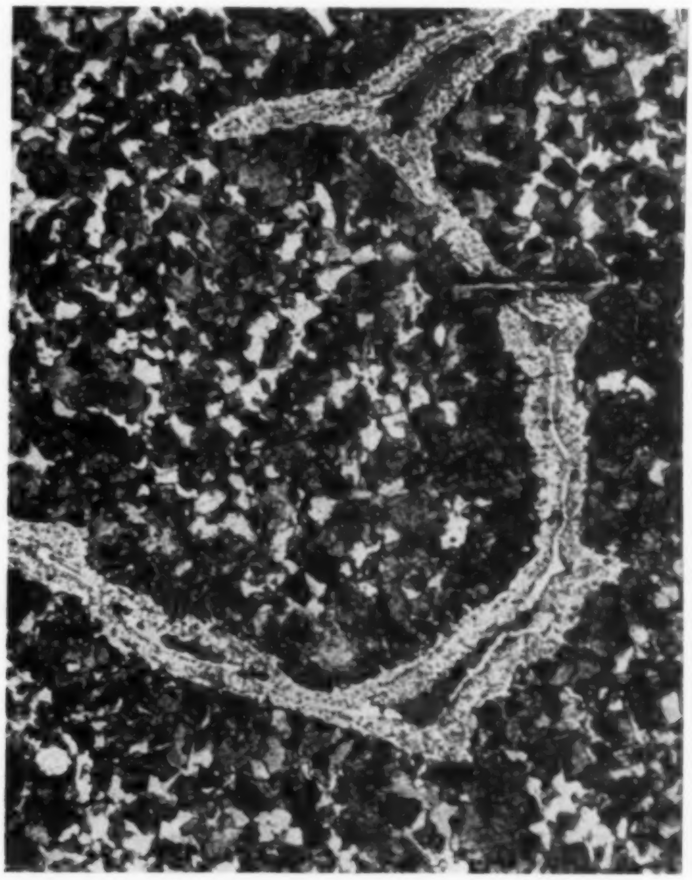


Fig. 11 (500x)



SLEUTHING
WITH A
MICROSCOPE

Fig. 12 (at right) — The surface of a part made of 5% nickel steel, showing a section perpendicular to surface which has been severely overheated on heating for forging. Magnified 100 times.

Fig. 12

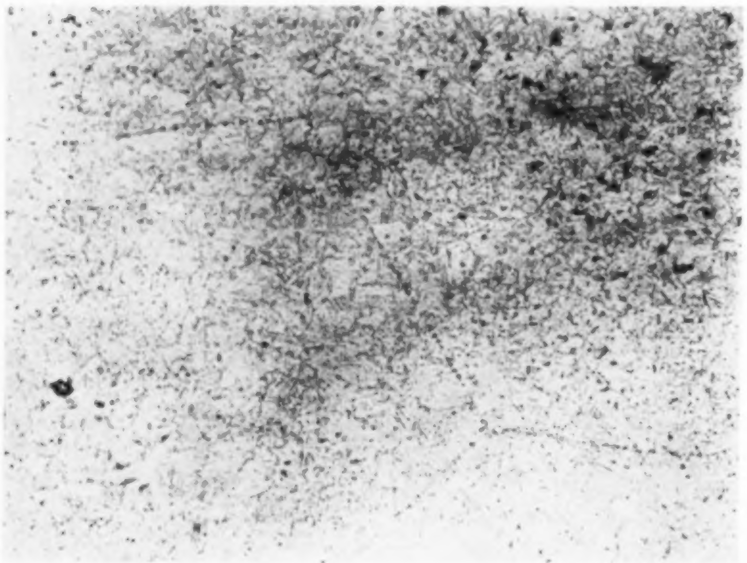


Fig. 13

Fig. 13 (at left) — A short distance in from surface the remnants of coarse forging structure may still be seen, which induces brittleness. Note the recrystallization produced by the subsequent heat treatment. This sample was etched 5 min. in 25% alcoholic HCl, repolished on final levigated alumina wheel, and then etched in 5% nital. (200 ×)

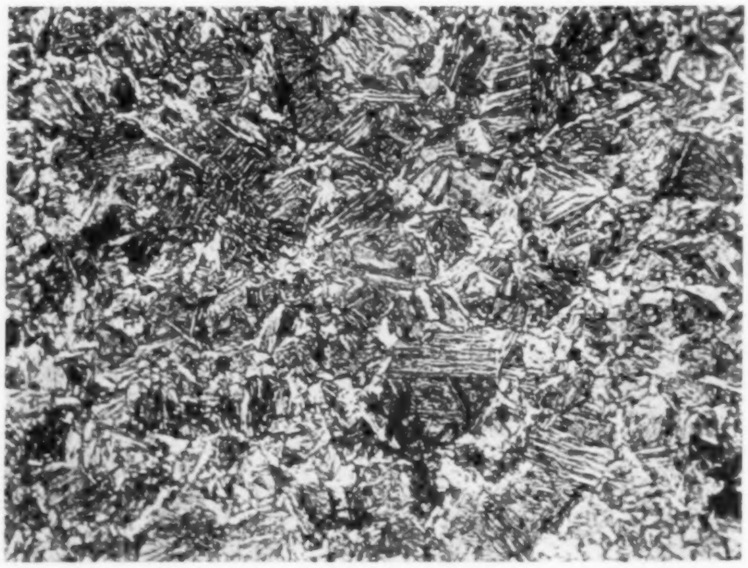


Fig. 14

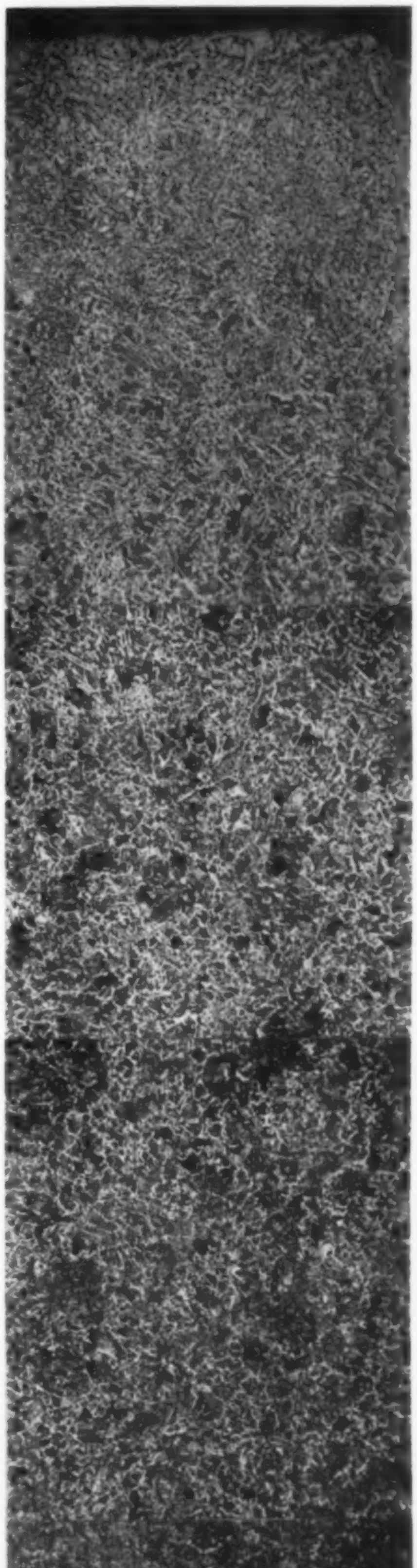
Fig. 14 (at right) — Ordinary examination would reveal a fine heat treated structure assumed to be tough. Nital etch, magnified 500 diameters.

EXCESSIVE HEATING

Figures 15 and 16 are photomicrographs of steel heated to an excessive temperature. A coarse oxide network destroyed the useful properties of the steel; heat treatment could not rectify this damage . . . . Fig. 17 shows the decarburized surface of a small forging heated for excessive time. This part has been heat treated after forging, but the surface hardness was far less than it should have been if properly heated or if 0.04 or 0.05 in. of surface had been removed.

Heated Too Long

Fig. 17, 100 x



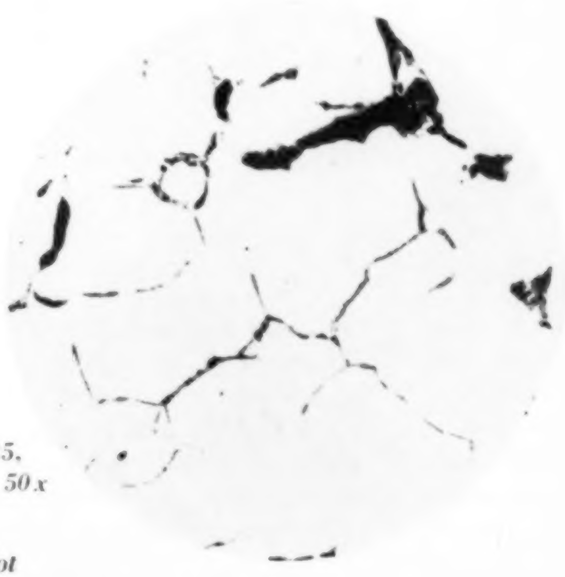
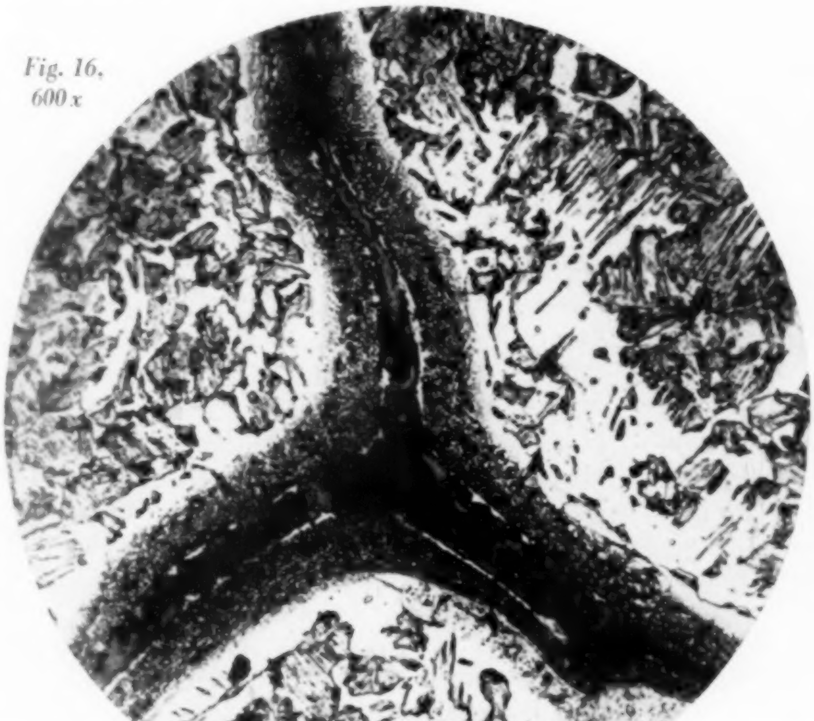


Fig. 15, Unetched, 50 x

Heated Too Hot

Fig. 16, 600 x



BEST TESTS FOR CORROSION AND ELECTROPLATES

By William Blum
Washington, D. C.

CORROSION has long been an important subject of consideration by the various metal committees of the American Society for Testing Materials. In fact this Society recently celebrated the twentieth anniversary of the first field tests on sheet steel conducted by its Committee A-5. It was therefore appropriate that it should hold at this time a Symposium on Corrosion Testing, in order to take stock of the experience gained from these and other investigations and to plan for the future.

The mere listing of the titles and authors of the six papers presented at the regional conference in Chicago, early in March, shows the obvious impossibility of adequately presenting, much less discussing, these subjects in a three-hour evening session. The only way in which the large amount of valuable material in these papers can be made effective is for the members, and especially the chairmen, of the numerous committees on corrosion to read them critically, and to discuss pertinent points in their committee sessions.

As each of the papers at the meeting on corrosion testing was in itself a summary, it is difficult to indicate much more than the scope in the following brief account.

A masterly discussion of "The Principles of Corrosion Testing," by C. W. Borgmann and R. B. Mears, emphasized the importance and value of *perspective* in attempting to standardize corrosion studies, including laboratory, field, and service tests. The authors are especially to be commended for condemning accelerated tests as a basis for predicting behavior in service. If and when such a test is shown to be a valid measure of expected service, it becomes in effect a "special property test," which in a given (but usually limited) field may prove valuable. A bibliography of 150 papers, which will supplement the printed paper, will be very valuable to students in this field.

Fundamental Principles

The multiplicity of committees and subcommittees of the American Society for Testing Materials and of other organizations that have planned and conducted atmospheric corrosion tests is so great that it is frequently difficult to correlate their results. This difficulty is increased by the variety of metals, alloys, and coatings tested, and the purposes for which they are to be used. In his paper on "Atmospheric Corrosion Testing," H. S. Rawdon has therefore rendered a great service in bringing together the salient features of such tests, and especially in pointing out the criteria that should govern decisions on such factors as the size and preparation of the specimens, and the installation and inspection. While it is certain

that no single set of standard conditions will meet the complex requirements, it is equally obvious that much simplification of procedure can be effected without sacrificing essential needs. One of his most far-reaching recommendations is that more detailed data should be secured regarding not only climatic conditions, but also atmospheric pollution, at the sites where tests are made.

In spite of its many limitations, the salt spray test is extensively used, especially in specifications for metals and protective coatings, for which, when intelligently interpreted, it may prove to be a valuable "special property test" as defined by Borgmann and Mears. No such test can be of value, however, unless the conditions are controlled sufficiently to yield reproducible results. E. H. Dix and J. J. Bowman in their paper on "Salt Spray Testing" summarized the variables which may affect the results. (They wrote with special reference to the testing of aluminum alloys, where the extent of corrosion is measured by the change in physical properties, especially elongation.) In addition to the design and operation of the box and spray equipment, and the control of temperature, which were fully discussed, more consideration might have been given to the strength, purity and hydrogen ion concentration of the salt solution, and to the nature of the mist. Experience in testing coated metals indicates that control of these factors is desirable, if only to permit more critical study of the variables above mentioned that are possibly more important.

Total Immersion Tests

D. K. Crampton's paper on "Alternate Immersion and Waterline Tests" indicated that such tests are even more empirical than the salt spray, and that many variables may affect the results. Here again, the testing of coated metals may involve closer control of some factors, such as the humidity during the exposure to air. Instead of having a "humid" atmosphere, it may be desirable to *control* the relative humidity throughout the test, for example at 60 or 70%.

"Total Immersion Testing," a paper by Robert J. McKay and F. L. LaQue, wisely confined itself to general principles, since the details must vary widely for different types of metals and solutions. This paper is essentially a statistical summary of 62 others on corrosion tests, and an effort to determine the extent to which each factor was defined or controlled. For example, 15 different units of magnitude or ratios were employed for reporting the extent of corrosion! All but three of these represented either *(a)* loss in weight per unit area per unit time, or *(b)* average penetration per unit time. If the American Society for Testing Materials were to adopt for each of these units a standard form (expressed possibly in both English and metric values), a great simplification and correlation of results would be fostered.

In their paper on "Soil Corrosion Testing," H. K. Logan, S. P. Ewing, and I. A. Dennison summarized their extensive experience on this very complex subject, which is so important in pipe line operations. As experience has shown that the nature of the *soil* is generally a more important factor than the exact composition of the metal, some rapid method of testing soils and of predicting their effects over long periods is highly desirable. The authors describe a method in which the current-potential relations are determined in a small cell in which the soil (with a controlled moisture content) is the electrolyte and the electrodes are steel. An equation is given for correlating the results of this test with the probable maximum depth of pit (which is usually the controlling factor in pipe line corrosion) to be expected in a given period such as 12 years. As the service data available are insufficient to evaluate the reliability of such predictions, the above method is presented at this time for study and not for acceptance as a standard.

Most of the above topics have a direct or indirect relation to the value of electroplated coatings, a subject upon which the American Electroplaters' Society, the National Bureau of Standards and the American Society for Testing Materials have cooperated during the past several years. The increasing interest in this field is illustrated by the attendance of about 75 persons at each of the two conferences held by the Joint Committee and related A. S. T. M. Sub-Committees.

Electroplating

Exposure tests of plated metals on steel have been conducted at six locations during the past five years, and the results were published in Bureau of Standards' Research Papers No. 712, 721, and 867. Similar and very extensive tests are now in progress upon plated coatings

on non-ferrous metals, including copper, brass, zinc, and zinc-base die castings.

The results of the inspections during the first year showed that the numerical system of rating is yielding results which are consistent and apparently significant. Especially in industrial locations, the appearance of tarnish films has made it difficult to observe the nature and extent of any actual corrosion. Preliminary tests showed that cleaning with mild abrasive powders nearly restored the original appearance and luster of chromium plated surfaces. It was also found that the occasional application of a thin film of oil or wax retarded corrosion and facilitated removal of the tarnish. It was therefore recommended by the conference, and subsequently approved by the Joint Committee, that in the near future some supplementary tests be started, in which new specimens will be cleaned and treated at regular intervals.

Pending the completion of such tests, no specific conclusions or recommendations will be published by the committee.

Colored Photographs of Corroded Metal

In connection with these exposure tests, C. A. Vincent-Daviss exhibited pictures taken in color of the specimens at the various locations. These are a great improvement over the usual monochromes, but there is need for further study to obtain a satisfactory, objective photograph of the bright, chromium plated surfaces. Mr. Vincent-Daviss' results show that this method of recording corrosion deserves consideration of all agencies that are conducting exposure tests or other corrosion tests, where the corrosion product is other than white.

The tentative specifications for plating on steel, adopted by the American Society for Testing Materials and American Electroplaters' Society in 1935, have not been extensively applied literally, though they have been followed in principle by many firms. In view of this fact, and that some new plated steel specimens are included in the exposure tests now in progress, it was recommended that the specifications be retained as tentative. It cannot be too strongly emphasized that in order for active committees to meet the needs of industry, their tentative specifications should be extensively tried out, and their value and limitations reported to the committees.

As the above and any other corresponding specifications for plating involve tests of quality, it was appropriate to devote considerable time to this subject. In the discussion, several members reported favorable results with a new transparent plastic, now called "Lucite," for mounting metallographic specimens.

Various details of methods for stripping coatings to determine their average thickness, and dropping tests and jet tests for local thickness were discussed, and also the "chord" method, described last year in Bureau of Standards' Research Paper No. 866.

Magnetic Test for Electroplate

A demonstration was then given of a new magnetic method devised by A. Brenner of the National Bureau of Standards for measuring the thickness of nickel coatings on non-magnetic base metals such as copper, brass, and zinc. Details of this method will be described in the Bureau's *Journal of Research* in the near future. Preliminary tests in several plants have shown that this non-destructive method may prove quite valuable in routine factory inspection of nickel plating on such parts as plumbing fittings, building hardware and automobile hardware.

Great interest was expressed in the *modus operandi* and the possibilities of this method at this conference as well as at other meetings where it has been demonstrated.

A short discussion of porosity tests, and of accelerated corrosion tests such as the salt spray, indicated that further study will be required to standardize procedures and interpret results.

The Sub-Committee expects to distribute exact descriptions of promising methods for trial and comment. Here again, it is to be hoped that a large number of persons will try such methods and report their experiences to the committee chairman (W. M. Phillips, General Motors Corp., Research Laboratories, Detroit, Mich.) All too often when persons try a new method, they either find it is satisfactory and say nothing, or else they find difficulties and condemn the method without communicating their results to those proposing it. Progress can be made only by cordial cooperation, not only of societies, but also of individuals.

Like the proverbial poor, corrosion will always be with us. Such conferences as those above mentioned will enable both producers and users to control even if not to eliminate corrosion, whenever the expense is warranted.

MODERN ANNEALING PLANT FOR A CONTINUOUS MILL

By A. L. Hollinger
and H. C. Weller
Surface Combustion Corp.
Toledo, Ohio

FUTURE industrial history will probably mark the present decade by the development and construction of enormous rolling mills for the production of steel sheets. Successful operation of these mills has required the solution of many subsidiary problems, not least of which is an economical method of annealing an exceedingly large tonnage of cold-rolled sheets to meet various exacting specifications. A description of the installation at Lackawanna plant (Buffalo, N. Y.) of Bethlehem Steel Co. will therefore serve as an excuse, if excuse be needed, for outlining the whole problem of bright annealing sheet steel.

In place of the multiplicity of handlings in the old style hand mill, the modern continuous method is strikingly direct. A slab, at correct heat, is rolled through a dozen powerful stands of rolls, operating at increasing speed, one after another in tandem, and so quickly that the long, wide ribbon emerges while yet at a red, plastic heat. After cooling, the scale is pickled off, and the strip-sheet is passed through three more stands of rolls in tandem, and reduced cold to the proper thickness and surface finish. After leveling and shearing to ordered size, the flat sheets are ready for annealing.

It is the A-B-C of physical metallurgy that cold work will harden and stiffen the soft, low carbon steel utilized for this product, and also that this cold-rolled sheet can be re-softened by annealing at a moderate temperature. The crystalline grains of iron (ferrite) in the hot-rolled strip are fragmented by cold rolling, and these fundamentally disturbed particles readily recrystallize if enough heat is given to increase the atomic mobility. A rather complicated relationship exists between the degree of cold work, the annealing temperature, the time at temperature, and the resulting grain size. The general problem of the steel mill metallurgist is to adjust the entire rolling program so that the customers' demands will be satisfied at the lowest cost. Sometimes this solution will put relatively more expense into the cold rolling department in order to cut the annealing cycle; sometimes the opposite is true. At any rate, the annealed sheet must pass close surface inspection and perform properly when stamped, drawn, welded and finished in the customers' shops. This in turn largely depends on grain size, uniformity in microstructure irrespective of direction of rolling, and freedom from internal strains and from age hardening.

Brief consideration of all these factors will indicate that the modern annealing department must not only be equipped to handle large tonnages of steel, but must be able to adjust the operations so that individual requirements may be met with certainty. This means (1) plenty

of *capacity*, (2) *accuracy* in the heating and cooling cycle, and (3) *flexibility* in being able to adjust this time-temperature program for each pile of sheets, if necessary. Finally annealing must be done in such a way that the surface is protected from scaling.

Further to emphasize the fact that *time* is an essential factor in such an annealing process as above defined, we may pause to note another possible softening operation — that known as normalizing. One essential difference between the two is that normalizing involves a heating to above the critical temperature of the low carbon steel, whereupon the ferrite almost instantly changes its entire crystallization system and takes the carbide into solid solution, in fact becomes an altogether new crystalline entity known as austenite. These microscopic austenite crystals also grow with increasing temperature, but the average size at any temperature depends more on the early history of the steel in the refining furnace than on the cold rolling program. On cooling back through the critical range, the reverse changes take place — that is, the carbide is precipitated and the ferrite crystals are re-formed, now free of strain, and of a size inherited from the parent austenite. These crystallographic changes occur so rapidly as to be completed during a furnace heating or cooling through the critical range, and the time for normalizing in a continuous furnace is measured in minutes rather than hours for annealing in a batch-type furnace. Here is not the place to discuss the reasons why normalized sheet is not suitable for many deep drawing operations required during later fabrication; this paragraph is warranted in order to emphasize the fact that the old-fashioned "process anneal" at sub-critical temperatures is still required, and this operation takes time because it involves sluggish atomic movements at comparatively moderate temperatures.

Economies of New System

The up-to-date method of annealing attains the old objective much more economically and surely by reason of three major improvements *(a)* in handling methods, *(b)* in heating methods and *(c)* in atmosphere control. In the old practice the sheets were piled on a movable base, a rather massive cover lowered and sealed around the base (first having placed some cast iron chips, charcoal or other carbonaceous substance inside), and this load slid into a furnace and heated by direct impingement of flame. The stout cover acted as a muffle to protect the work, and the reaction between the carbon and the contained air prevented the sheets from scaling.

In the new practice the sheets are piled on a permanent base, an inner cover made of light steel placed over the pile, sealed at bottom and filled with a prepared gas, neutral toward steel or even deoxidizing in nature, and then a heating unit in the form of a portable furnace covers the entire assembly. The heat is generated by gas flame, but this flame, instead of circulating freely around inside the furnace, is confined inside tubes of heat resisting alloy, heating them to incandescence so they in turn form radiators. It is obvious that this arrangement facilitates the introduction of a constant supply of protective gas to the pile of sheets inside the inner cover, reduces the amount of extra material to be heated to a small proportion of the useful load, economizes greatly in cost and maintenance of protective covers, and gives a fixed source of heat placed in the most efficient position and under accurate control. There appears to be no limitation to the horizontal dimensions of the pile of sheets; vertically the pile cannot be much higher than 5 ft., else the load will cause sheets at the bottom of the pile to weld one to another.

Accompanying photographs show details of the complete modern installation made by Surface Combustion Corp. at the Lackawanna plant of Bethlehem Steel Co.

The annealing department occupies one bay approximately 1000 ft. long by 100 ft. wide. Forty-four radiant covers, with their bases, are arranged along each side. The side walls run up to a high clerestory above the craneway to provide a row of windows and ventilators.

The bases are in three sizes designed for sheets 75x220 in., 84x186 in. and 90x250 in., piled 60 in. high. (All of the bases and covers can also be used for coiled strip.) The weight of a full load of sheets is therefore approximately 100 tons.

It will be noted that these bases are solidly founded on piers and are substantial enough to take the heavy loads. Eight pipe connections pass up through each foundation, two for entrance of prepared atmosphere, six for thermocouple leads. The inner cover is a lightly braced shell, made of $\frac{3}{16}$-in. common steel. Its lower edge extends into a sand seal. A slight positive pressure is held on the inner atmosphere at all times and temperatures; slight fil-

tration of gas through the sand seal gradually fills the space between outer and inner cover and thereby protects the inner cover from all but minor scaling.

The outer covers are of the horizontal radiant tube type; the tubes are heated with a mixture of blast furnace and coke oven gas, containing 300 B.t.u. per cu.ft., supplied at a pressure of approximately 20 oz. The mixture is carefully maintained as to content and calorific value, 307 B.t.u. being the maximum allowable.

On page 392 a cover is shown being lowered over a load of sheets; corner guide stakes prevent damage either to inner cover or radiant tubes. Only one pipe connection is necessary to the fuel gas main, the combustion gas being collected in side downtakes which connect to an underground flue by appropriate sand seals. Electric power is plugged in to drive the blower for combustion air and spent gas eductors.

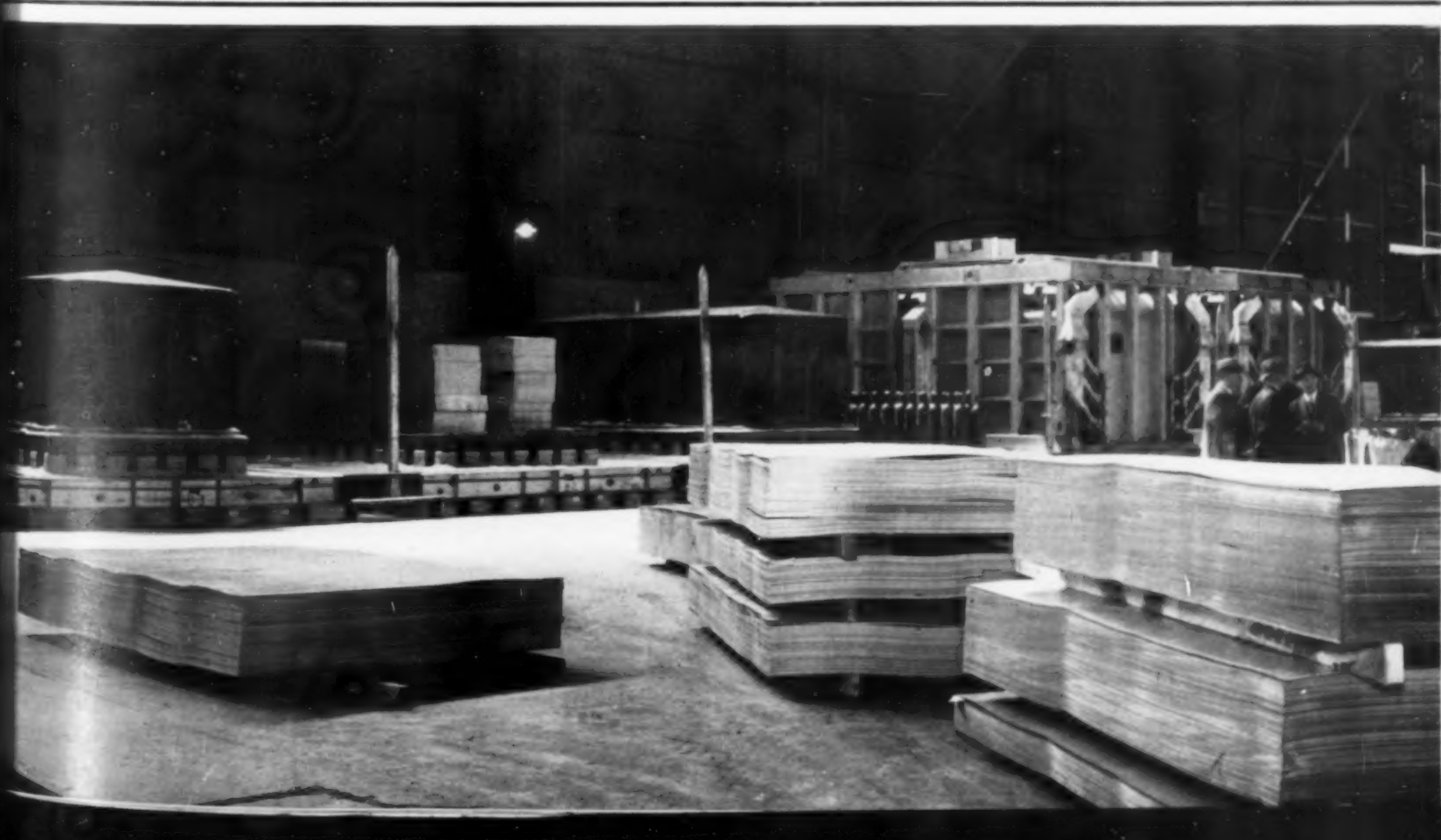
Substantially constructed of plate steel, supported by H-beam columns with all seams and joints welded gas tight, this cover is lined with light weight insulating refractory walls and a sprung arched roof. It is equipped with three tiers of horizontal U-bend heating elements. Each of these tubes has the open ends securely bolted at openings through the outer casing, and inside rides freely on brackets, thus permitting full expansion and contraction.

The diffusion flame principle of heating is used for supplying heat to the tubes. As will be explained later in this article, this method of combustion produces a long, luminous flame of controlled turbulence and heat liberation, and lends itself ideally to the internal firing of tubes. Most of the heat is generated in the two lower tiers of U-tubes. The natural up-sweep in the space between inner and outer covers brings enough heat to the upper part of the pile so that it heats from edge toward center at a substantially uniform rate. Obviously, it would do little good to place heaters either below or above a pile of flat sheets, since the insulating effect of the laminated surfaces would effectually stop heat transmission.

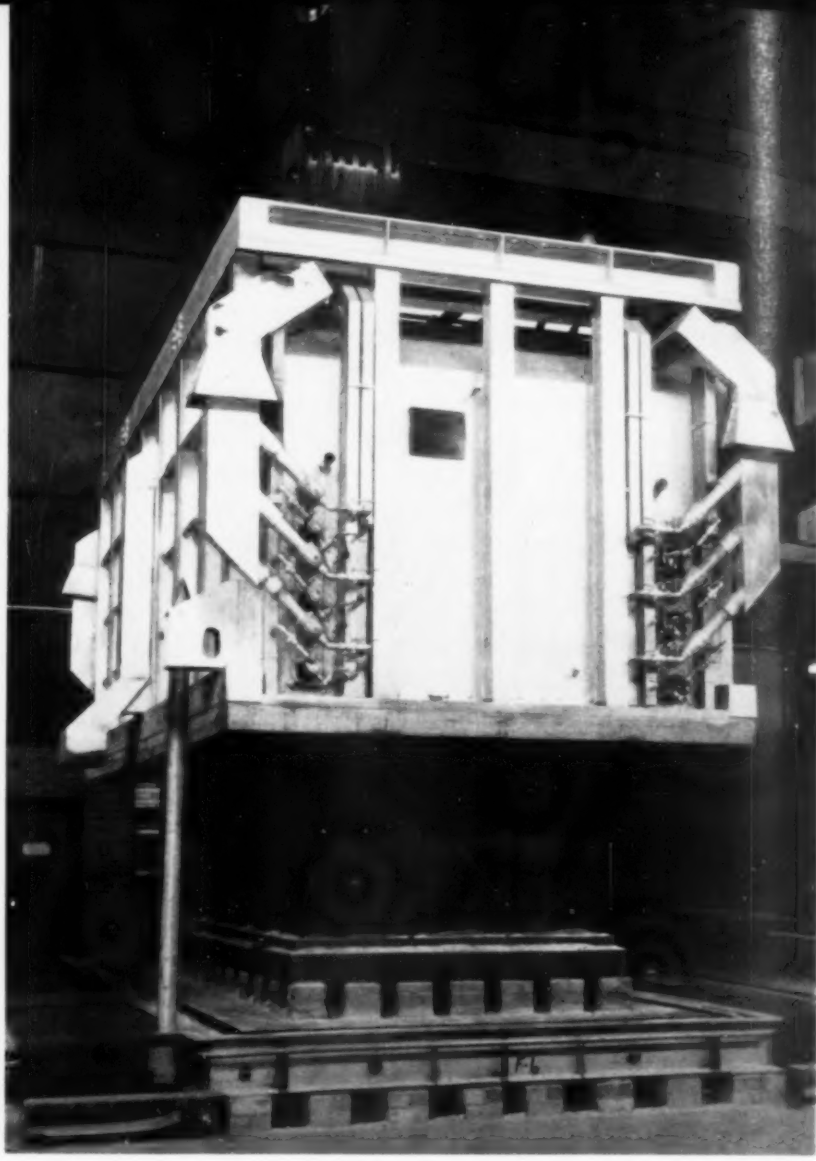
An eductor at the discharge end of each U-tube, powered by an air blower attached to the cover, keeps the tube under a negative pressure and the suction produced at the inlet end permits the gas to unite with the required amount of air for complete combustion at very low velocity without turbulence. The flame thus procured proceeds with uniform velocity and is complete (negligible CO) toward the discharge end of the tube.

Should a leak occur in a tube during operation, immediate repair or replacement is not necessary. It can be postponed until production permits, as the tube while in operation is always under a negative pressure, and the protective atmosphere can never be polluted by products of combustion.

View Across Central Aisle in Annealing Department of Lackawanna Mill. Ranged along the wall may be seen part of two rows of 44 bases. Left to right: Cover placed ready for furnace; sheets being piled; pile inside cover cooling to room temperature; two outer covers under fire



In preliminary tests at Seneca Steel Division, Blaisdell, N. Y., wherein many runs were made with a dozen or more thermocouples in selected positions in the pile, the proper positions for control couples were determined, one in the pile of sheets quite near a lower edge, and a second at the center of the pile well within the upper portion. (Four other couples are also embedded in the pile at critical positions, and a complete time-temperature curve made from each.) As soon as the hot cover is lowered in place the tubes are fired at maximum rate. Heat received by the side of the pile by radiation is conducted rapidly inward, and while the edges of the sheets reach annealing temperature first, the center does not lag far behind. In practice, therefore, the thermocouple near the edge controls heat input as soon as it reaches correct annealing temperature (say 1275° F.), and the deeply buried thermocouple tells when the annealing cycle approaches the end — the whole pile then being uniformly heated.



A Pile of Sheets Is Within Inner Cover and Movable Outer Cover (the Heating Unit) Is Being Lowered in Place

Two sets of supplementary fuel gas controls are used — one controlling the burners on the two lower tiers and one controlling those on the top tier. This method puts heat at a maximum rate into the work at the bottom, continuously; heat is shut off the top tier when the control reaches the set temperature and the two lower tiers of U-tubes supply all of the heat the pile of sheets can absorb without overheating the edges.

The tubes are made of heat resisting castings containing about 25% chromium and 12% nickel. This analysis holds its strength remarkably well at temperatures up to 2100° F. and, when exposed to oxidizing atmospheres, to sulphur and its oxides, shows no indication of surface deterioration. It has been proven by long use in furnace parts, such as pushers, rollers and conveyors. Cast alloy radiant tubes have actually been in operation for nearly three years without indications of surface oxidation. Since they are subjected to far less abuse than furnace parts, their life should be long.

Controlled cooling is an essential step in correct annealing. It is obvious that this may be effected by proper manipulation of the covers. After the gas is shut off the tubes, temperature drops very slowly, since the furnace is excellently insulated. Somewhat more rapid cooling may be had by raising the outer cover a few inches and blocking it there. As a general rule, the cover is removed promptly and placed over a cold charge awaiting anneal, and the inner cover (with its contained protective atmosphere) protects the hot pile while it cools freely by radiation. Any desired cooling condition may be secured by leaving the outer cover in place and blowing the correct amount of cold air through the U-tubes (a common method in annealing "black iron" which is later pickled and galvanized).

Protective Atmospheres

It is impossible to discuss comprehensively the chemical theory of protective atmospheres. Fortunately for process or softening annealing, the conditions are simplified by the moderate temperature of operation, and all actions are so slow at temperatures below 350° F. that they have no observable effect. It has been found in practice, therefore, that almost any clean fuel gas, burned in an insufficient supply of air, will protect steel during the annealing operation if it is dried sufficiently. Given a supply of natural gas, as at the Lackawanna plant, it may be practically burned to the following analysis (dry basis by volume): CO_2, 5 to 6%; CO, 9 to 10%; H_2, 10 to 11%; and N_2, balance. At all temperatures up to 1300° F. a mixture of CO_2 and CO will tend to reduce any iron oxides present on steel (and therefore protect clean steel from scale) if the proportion by volume of CO is half again as large in quantity as the CO_2.

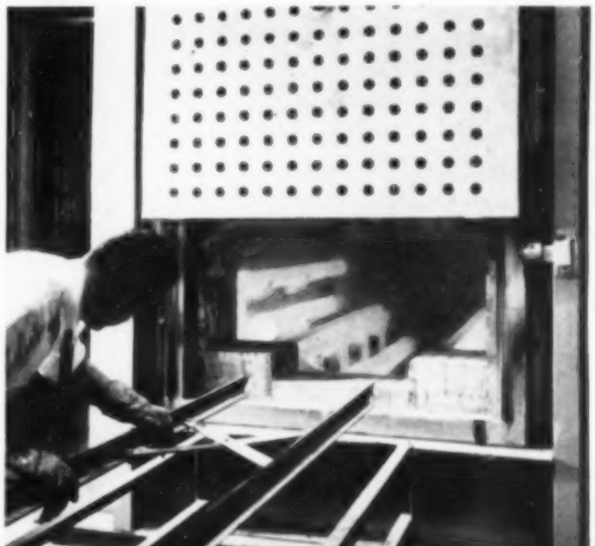
The hydrogen-to-moisture ratio is a different matter. Any fuel gas rich in hydrocarbons will produce large quantities of hydrogen and water vapor on partial combustion, and as pointed out by Mr. Hotchkiss in the leading article in this issue, the relative potency of the two gases changes rapidly as the temperature falls. In fact, at 350 to 400° F., which is the lower limit of activity in the cooling mass, there should be at least 20 times as much hydrogen as water vapor in the protective gas mixture, else the latter will tarnish the steel's surface.

The practical problem is, then, to dry the prepared gas to the point where it will be innocuous, and fortunately if it is cooled to 35 to 40° F. and the condensed fog removed, the correct result is achieved.

The view on page 394 shows three of a battery of four gas preparation units, made by Surface Combustion Corp., and installed at the Lackawanna sheet mill. Each of these "DX gas machines" has a capacity of 15,000 cu.ft. of prepared gas per hr. Underneath the large, horizontal, combustion chamber are located gas and air control, blowers, cooling coils for refrigerant and other auxiliaries. The natural gas and air mixture is introduced at the rear of the refractory chamber. The hot gases go through some jacketed pipe, giving up some of the heat to the cold, finished gas on the way to the annealing covers, and thence into a tower where they are sprayed with filtered water. (Clean water and clean air are both scarce articles at most steel mills.) This brings the temperature down to about 100° F. and washes out any ash; most of the entrapped fog is then cleared by passage through a second tower filled with porous tile. Gas saturated with moisture is then cooled to the required temperature (usually about 40° F.) by passing through an ordinary surface condenser, the cooling medium being any of the liquids used in household refrigerators. Condensed fog is again cleared by a baffle tower, and the prepared gas, now at 40° F. and containing only the water vapor representing dew point at that temperature, is warmed in the heat recuperator first mentioned and enters the gas mains serving the annealing department.

A word might be said of the hazards of handling this DX prepared gas. Since it is partly burned, it should be less liable to explosion and fire than ordinary fuel gas, and in fact this is so. Minor leakage around sand seals and losses from flushing an empty cover do not cause toxic effects because the carbon monoxide immediately is diluted in the air of the very large building, always adequately ventilated.

At the start of an annealing cycle, the prepared gas enters the inner cover (now containing air) and as the temperature creeps



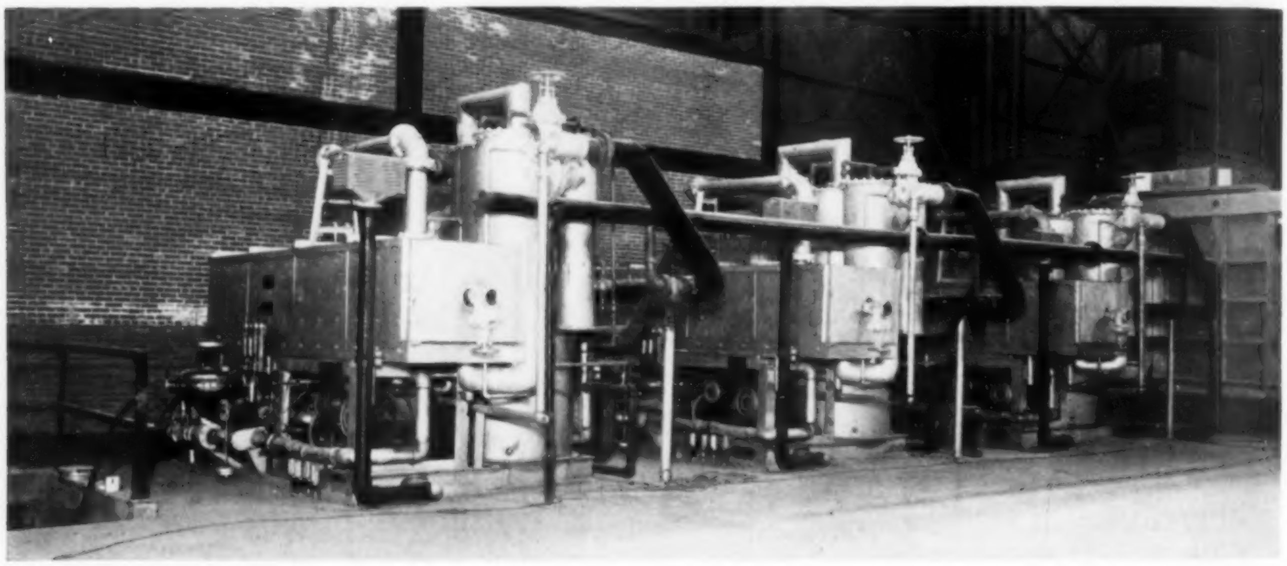
Radiant Tubes, at Heat, in Small Ceramic Furnace, Showing Uniformity of Temperature, End to End. Courtesy Ferro Enamel Corp.

up, gradually combines with the atmospheric oxygen. Pressure is raised so considerable gas seeps out under the sand seal and enters the space between inner and outer covers, also consuming oxygen there.

Combustion in Radiant Tubes

It will be observed that the radiant tube gives the advantages of an electric resistor, as regards non-contamination of the furnace atmosphere, and with a cost advantage due to the fact that a B.t.u. can be had from cheap fuel gas (even when flue losses are considered) for a lower cost than from an electric resistor at maximum efficiency. Radiant tubes, as first developed and applied to industrial heating operations by Surface Combustion Corp., derive their advantages of high thermal efficiency from the intensity of controllable radiant heat emissivity of diffusion-of-flame combustion.

The relative merits of premix burners and luminous flame combustion have been widely discussed and a conflict of statements has shrouded the facts. If gas and air are thoroughly premixed in correct proportions, combustion occurs instantaneously and the resultant heat liberation is chiefly by convection currents near the burner ports. If gas and air are not premixed, a luminous flame results as the partial or delayed combustion of the hydrocarbons progresses. In a true diffusion-of-flame combustion, gas and air are introduced into the furnace chamber in parallel layers without relative motion between gas and air which unite and burn between the interfaces of such layers so that combustion propagates at a constant rate throughout an allocated length. (This was described at length by W. M. Hepburn in Metal Progress, September 1932.) Therefore, the great difference between a luminous and a diffusion type flame is the rate of flame propagation, the method of mixing and the relative motion of gas and air streams. Luminous flames can be produced with any kind of commercial gas fuel; the rate of heat transfer and the composition of the flue gases are the only difference.



Part of a Battery of Gas Preparation Units Wherein Natural Gas Is Partly Burned, Dried and Warmed Ready for Use as Protective Atmosphere

If radiant tubes are to be fired internally, the questions arise, "What type of flame is most suitable for the ultimate in heat transfer from the hot gases to the surrounding tube?" "Under what conditions is a diffusion type flame more efficient than a premix flame?"

To answer these questions correctly, a determination of the respective flue gas temperatures for the two types of combustion under the same postulated conditions as size of combustion tube, rate of gas input, wall temperature and initial air and gas temperatures will be necessary. The burner that will give the lower flue gas temperature naturally will be the more efficient.

The temperature history of a premix type flame shows that a different curve is required for each rate of gas flow. This does not apply to a diffusion type flame. Its temperature will normally be lowest as it issues from the burner and will rise to a maximum as combustion proceeds within the tube, then fall again from a point near the middle to the end of the flame. By varying the port dimensions, it is possible to control the heat liberation over either short or very long flames.

If, therefore, a diffusion type flame fires a radiant tube under the same postulated conditions as the premix flame, the picture of heat distribution changes entirely. The reason is the higher heat emissivity from a radiant flame since the emissive properties of incandescent carbon particles are added to the radiation of the CO_2 and H_2O gases which are part of any type of combustion.

The energy emitted from those particles suspended in the flame has two sources, namely, from the combustion of the surrounding gases and from the oxidation of the carbon particle itself. We may safely assume that no temperature difference exists between the hot gases and the carbon particle, because the heat transmission of the hot gases will be higher than the energy radiated by a single particle of carbon. In analogous manner, the total radiant energy emitted to the tube wall proper will be a direct function of the mass of carbon particles set free by the diffusion-of-flame combustion, and it is evident that the flame procured has a higher luminosity than a premix type flame. Radiation from the carbon particles readily compensates for the rapid decrease in radiation of the CO_2 and H_2O gases as the flame traverses the tube, resulting in uniform heat emissivity. Since the over-all heat coefficient of the flame has thus been increased, it further follows that the temperature difference between the flame and the surrounding tube wall will be less than in the case of a premix type burner.

The method of diffusion-of-flame combustion with its inherent qualities of a long, highly luminous flame, absence of turbulence, and controllability of heat liberation, lends itself ideally to internal firing of tubes. The operation of the tubes is very simple. In addition to these advantages, means as described earlier in the article have been developed whereby the flame itself is always kept under negative pressure or suction, so that a small leak will not contaminate the heated chamber.

MOUNTING AND POLISHING OF TIN ALLOYS

By H. J. Taffs

Abstracted from Journal, Royal Microscopical Society, Vol. 56, p. 300 (1936)

BESIDES difficulties in the polishing and etching of tin, tinplate and tin alloys for microscopical examination, a special procedure is sometimes essential for mounting the specimens, for the tin is often present as a thin coating on steel, copper or brass, or as a bearing alloy in the form of a relatively thin layer on steel or bronze, while in soldered joints the tin alloy is again present as a film. Although it is usually advantageous to copper plate for complete protection of the edge of the specimen, this does not give sufficient bearing surface with which to polish; hence the necessity for mounting.

Mounting difficulties are mainly of finding a plastic mountant which hardens to something near the hardness of the metal under examination, without the use of heat, and yet is chemically inert to the etching reagent used. Sealing wax and golaz wax may be cast at 250 and 230° F. respectively, but are so brittle they do not protect the specimen when cut with a hacksaw and are soluble in alcoholic etching reagents. Picein, a soft, black, plastic wax, has the same drawbacks, except that it is insoluble in alcohol, but it is softened by ether or acetone.

Sulphur may be cast slightly above 233° F., its melting point. It is, however, quite brittle. It polishes easily, but tends to form an objectionable film over the polished specimen after polishing, and also after etching.

Spence metal is obtained by mixing iron pyrites, sieved through 90 mesh, with flowers of sulphur in the proportion of 3:2. The mixture is heated to 360° F., stirred well, and cooled. At 265° F., the mixture, previously viscous, suddenly becomes fluid, when it is cast. It affords good protection when cutting the specimen and is satisfactory with most etching and drying reagents. It is, however, very hard.

Wood's metal melts at 155° F.; it is a soft alloy and protects the specimens excellently when they are being cut, but tends to clog the polishing papers, and *(Continued on page 432)*

Gustaf Waldemar Elmen

INVESTIGATOR, PHYSICIST AND INVENTOR

PERMALLOY is a magnetic material which is not widely used in industry, and even in the communications field — where it is indispensable — it is not made in what might be called tonnage, nevertheless its discovery and the later development of whole families of new magnetic alloys well warrants a salute to the man whose name is inseparably connected with this branch of knowledge. GUSTAF WALDEMAR ELMEN ranks high among the eminent living metallurgists and scientists, worthy of inclusion in any album of notables.

Elmen's studies in magnetic materials, carried on for the last 30 years, had a somewhat casual beginning, and did not spring from any particular interest he had in this field during his early life. He was born near Stockholm, Sweden, on December 22, 1876, and was educated in the public schools of Stockholm. In the summer of 1893 he came to the United States to join his brother in Nebraska, and in the fall of that year entered Luther Academy, in Wahoo, Nebraska. Graduating in 1896, he entered the University of Nebraska where he majored in physics and mathematics; becoming Bachelor of Science in 1902, he took graduate work in physics, and received his Master of Arts degree in 1904. After two years with the General Electric Co., he joined the Engineering Department of the Western Electric Co. in 1906, which became Bell Telephone Laboratories in 1925, and he has continued with this organization ever since.

When with the General Electric Co. Elmen had done a little work on the hysteresis loss in silicon steel and, possibly as a result of that, his first assignment with the Western Electric Co. was to investigate certain difficulties that had cropped up with the permanent magnets of bell-ringers. This work led to an investigation of the effect of heat treatment on the characteristics of the magnets, and to a realization of the great importance of a specific and accurate temperature cycle. This early impression of the importance of heat treatment stood the young experimenter in good stead in later work.

Subsequent studies on the iron wire used for the cores of loading and repeating coils emphasized the importance of heat treatment, but the discovery that silicon steel, which had proved so generally satisfactory as a core material, was not satisfactory for loading coils started him on the investigation of other possible magnetic alloys. (These coils, by the way, are generally used in cables of any length to reduce losses and the distorting effect of unequal losses in the various frequencies transmitted. The mathematical theory had been worked out, but the practical application with available materials required the construction of bulky attachments.)

At this time a nickel-iron alloy, containing 25 to 30% nickel, was used for resistance wire such as the heating elements in toaster stoves. Nickel, however, happens to be one of the magnetic materials, and this fact, coupled with the availability of this particular resistance wire, led Dr. Elmen to investigate its magnetic characteristics. He carried his experience in heat treatment into these studies, and from the particular alloy available obtained initial permeabilities between 1000 and 2000, and while these values have since been multiplied many times, remember that they were then compared to iron, between 100 and 200, and silicon steel, between 500 and 600.

This was a startling discovery, and entirely unexpected to all save perhaps Dr. Elmen himself, who from his close study of magnetic materials over a long period of time had conceived certain possibilities that were far from obvious. Because of its high permeability, this heat treated nickel-iron was christened "permalloy," and was at once proposed for continuous loading of submarine cables. Other uses also suggested themselves, but the War delayed any thorough investigation of such things.

When the armistice permitted events to take their more normal course, Dr. Elmen again turned his entire attention to magnetic alloys. It was not, however, the immediate practical application of permalloy that absorbed his thoughts. A whole new field of study opened up before his imagination. There were an infinite number of possible combinations of iron and nickel, and an infinite number of possible heat treatments for each that called for systematic investigation. He could not be at all sure that the particular combination of iron and nickel that had proved so promising in these pre-War experiments was the best. With so fertile a field to work in, he readily secured funds for more adequate equipment, and thus armed, proceeded on a systematic investigation.

As a result of this work, he was able to show that the greatest permeability was obtained by an alloy consisting of 78.5% nickel and 21.5% iron, which — known as 78.5% permalloy — has since found wide usefulness. A 45% permalloy also was promising for certain applications. He also tried adding other metals to the alloy in small amounts. Chromium particularly seemed

to offer advantages because it gives a high resistance to the material, and thus tends to reduce the eddy-current losses.

The principal magnetic properties of these alloys are summarized in the data sheet (page 285) of last month's METAL PROGRESS. It again should be emphasized that before Dr. Elmen began his studies of nickel-iron alloys in the second decade of this century, pure iron was thought to be the best magnetic material available, and where low hysteresis losses were needed and large fluxes at small magnetizing forces, efforts were made to secure as pure an iron as possible. With the discovery of permalloy, however, characteristics that were undreamed of before became easy of attainment. With Armco iron, for example, which represents the best grade of commercially pure iron obtainable, the maximum permeability is below 10,000, while with permalloy, values in the neighborhood of 90,000 are readily obtained. The hysteresis loss of permalloy over a cycle extending to 5000 gausses, is only about a sixteenth of that of Armco iron over the same cycle. It is when only *small* magnetizing forces are involved that permalloy attains its greatest value. The initial permeability of permalloy, for example, is of the order of 10,000 while that for Armco iron is about 250. While a magnetizing force of 1.0 oersted is required to produce a flux density of 5000 gausses in iron, a force of less than 0.1 oersted will produce the same flux density in permalloy.

It is for such reasons that permalloy and its allied alloys are of particular importance in the communication field, where because of the small currents commonly employed, the magnetizing forces are low. It is permalloy that was primarily responsible for increasing the speed of transmission over submarine telegraph cables to about four times its former value, and for reducing loading coils to one-third their former size.

It is permalloy again that has permitted the redesign of relays and many other pieces of telephone apparatus to secure much smaller size and more satisfactory characteristics. These useful and practical applications, invaluable as they have proved to the communications industry both technically and economically, do not alone truly gage the importance of Elmen's discovery, for it unexpectedly gave access to entirely new groups of magnetic materials.

For when the iron-nickel binary system was reasonably well understood, the work had only begun! There are three magnetic metals — iron, nickel, and cobalt. Since alloys of nickel and iron had proved so advantageous, it was not unlikely that alloys of iron and cobalt, of cobalt and nickel, or ternary compounds of all three would prove of equal or greater value. The work was therefore repeated for iron and cobalt, and for cobalt and nickel. The latter alloys proved of little immediate interest, but the iron-cobalt series gave alloys in the mid-range that maintained their high permeabilities up to higher flux densities than any other magnetic material, the maximum occurring at an induction of about 12,000 gausses. Because of their enduring permeability, the alloys in this group were called permendurs.

With the three possible binary combinations explored, there remained the more extensive field of ternary alloys. Some indication of the regions more likely to be favorable was obtained from the behavior of the binary alloys, and systematic study revealed a large group of promising alloys which were called the perminvars — the name arising because of the constancy, or lack or variability, of the permeability at low flux densities. For these alloys, also, the effect of adding small amounts of other metals such as chromium and molybdenum had to be studied, and also, of course, the effect of various forms of heat treatment.

As a result of this vast and fundamental work, there is now available a whole family of new magnetic alloys, not alloys with characteristics somewhat better than those of previous alloys, but alloys with characteristics so different as to constitute distinctly different genera. Moreover they have characteristics and combinations of characteristics the existence of which had been entirely unsuspected when Dr. Elmen began his work. His is one of those rare intellects that is able to see important significances in small incidents which are generally ignored, and he persevered in his studies until germinal significances became obvious facts and took a recognized place among scientific phenomena.

The importance of this work has been generally recognized. Gustaf Waldemar Elmen was awarded the John Scott medal by the City of Philadelphia in 1927 and the Elliott Cresson Medal by the Franklin Institute in 1928. In 1932 the honorary degree of Doctor of Engineering was conferred upon him by the University of Nebraska. He is still actively engaged as Research Physicist at Bell Telephone Laboratories in New York City and is continuing his studies of magnetic materials.

A NEW TEST FOR RELATIVE SLIDING WEAR

By Donald S. Clark
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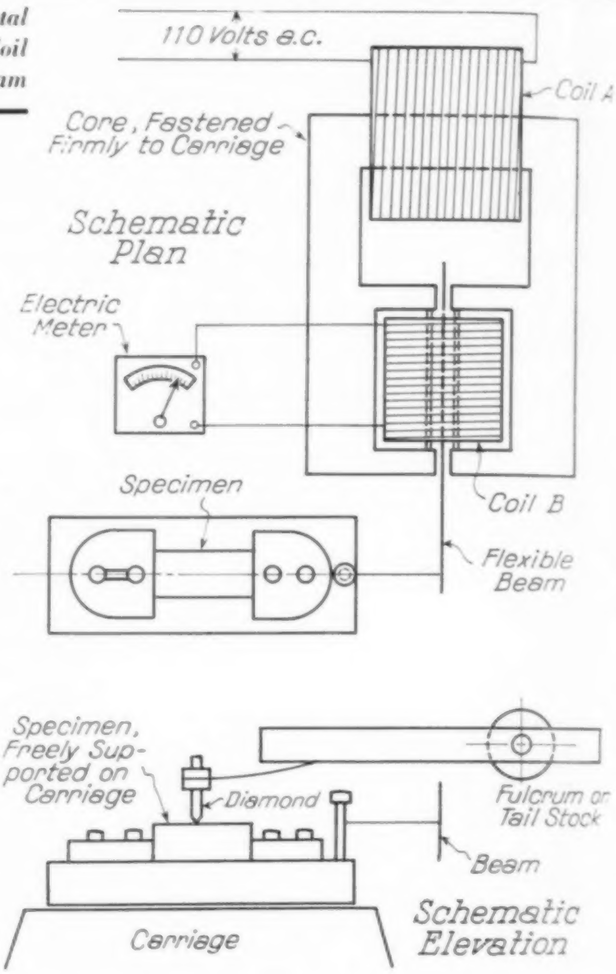
THE PROBLEM of determining the relative wear resistance of metals is probably one of the most difficult tasks confronting the engineer today. Many attempts have been made to devise a test in which the wear resistant properties of metals could be determined. The principal difficulty has been in knowing what variables are of importance. Hence, great care must be exercised when designing or selecting a machine for wear testing in order to simulate the conditions of service.

The present authors designed and built a machine in which conditions of sliding wear were reproduced and which gave results commensurate with actual field tests. Tests made on this machine, which was described by the junior author in METAL PROGRESS last month (page 281), require considerable time and special specimens. Since one object of a laboratory test is to obtain comparative results in as short a period of time as possible under controlled conditions, it was the authors' next object to find an accelerated test by which the resistance of materials to sliding wear could be determined and correlated with service conditions. It is the intent of this paper to indicate a method whereby this objective might be reached and to show some of the preliminary results already secured.

As shown by the article last month, the tests on our special wear testing machine indicated that in most cases wear took place by the scratching of one material on another which sometimes formed a series of grooves in the direction of motion. A study of these conditions indicated that rapid test results might be obtained by observing the action of a hard point in scratching the surface of the materials. This at once brings to mind scratch hardness methods which have been devised by many investigators, notably the microcharacter of Bierbaum; however, the present authors and others have found that scratch hardness has not been correlated with wear.

In considering the mechanism of wear, it is apparent that energy is absorbed in friction, in the deformation, and finally in the removal of material from the specimen. It therefore seems reasonable that any test that may be devised to determine the energy absorbed in the process of wear will give correlative data. Thus, if a diamond point, ground to the proper dimensions and loaded with the proper weight, be drawn over a polished specimen at a very low velocity thereby cutting and removing material from the surface, a force will be necessary to move the diamond and can be measured with the proper instruments. Knowing the shape of the point, the width of scratch and the force exerted, the energy necessary to remove a unit

Force Required to Remove Measured Amount of Metal in Scratch Is Estimated From Current Induced in Coil B by Movement of Armature Attached to Flexible Beam



volume of the material by this method can be computed.

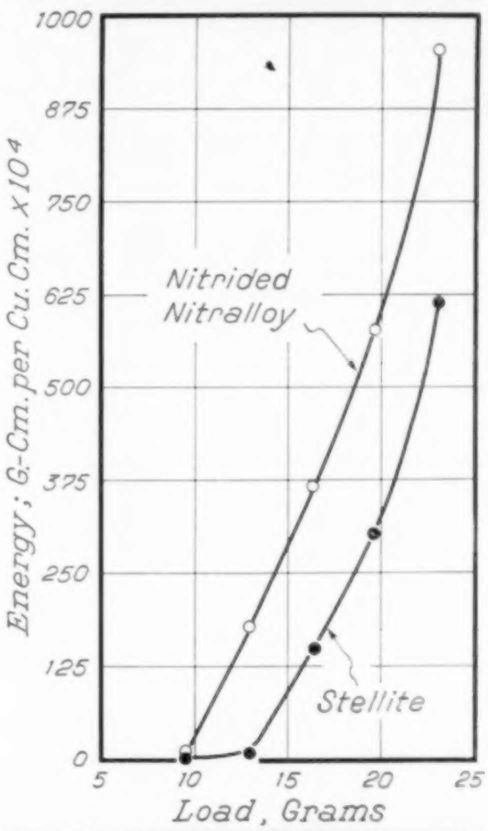
Investigations on scratch hardness have shown the corner of a cube to be the most satisfactory cutting point. The diagonal is maintained perpendicular to the surface being cut, and the intersection of two of the faces forms the leading edge of the cutting point. If the point is maintained in this manner, it can be shown mathematically that the depth of cut is proportional to the width, and the cross sectional area is proportional to the square of the width. The volume of material removed is the product of the area and the length of travel. The work required to produce the scratch is the product of the force necessary to move the diamond and the distance through which it moves, and the work per unit volume is proportional to the force divided by the square of the scratch width expressed in symbols, $E = f \div w^2$, where E is the energy required to scratch per unit volume of material, f is the force required to produce the scratch, and w is the width of the scratch produced by the diamond point.

In the investigation carried out by the present authors, the specimen was prepared as for metallographic examination and mounted on a holder which was freely supported on the carriage of a lathe. Two views are shown of the actual machine together with a schematic diagram to show more clearly the electrical circuit. (The latter is reproduced from METAL PROGRESS for last September, where a brief account of this development was given in a letter to the Editor.) The specimen is clamped in a holder which is freely supported on the carriage C by hanging it with four wires from an overhead plate, which in turn is securely fastened to the carriage of the lathe. The diamond D is elastically fastened to a fulcrum on the tail stock of the lathe by a piece of spring brass. The specimen holder is connected by means of a link E to a beam F which is fastened to the armature of the magnetic coil. The armature of the coil is elastically held so that the deflection is proportional to the force required to move it. Any deflection of the armature induces a current in the auxiliary coil, which is measured on the multimeter.

In operation, the specimen is moved under the diamond point at a constant rate. The scratching force exerted by the diamond tends to move the specimen with respect to the car-

Equipment Viewed From Tail Stock End; Viewed From Another Angle on Opposite Page

riage of the lathe, but this movement is limited by the deflection beam which is also carried on the carriage. The deflection of the beam, which is fastened to the armature of the magnetic circuit, can be determined by the current induced in the auxiliary coil. The circuit is calibrated with known forces on the beam so that the force required to scratch with the diamond can be determined. The width of scratch is then measured at high magnification with a filar micrometer. The energy is calculated as outlined above.



Curves Showing Energy Versus Load (Depth of Scratch) Run About Parallel for Stellite and Nitrided Nitralloy

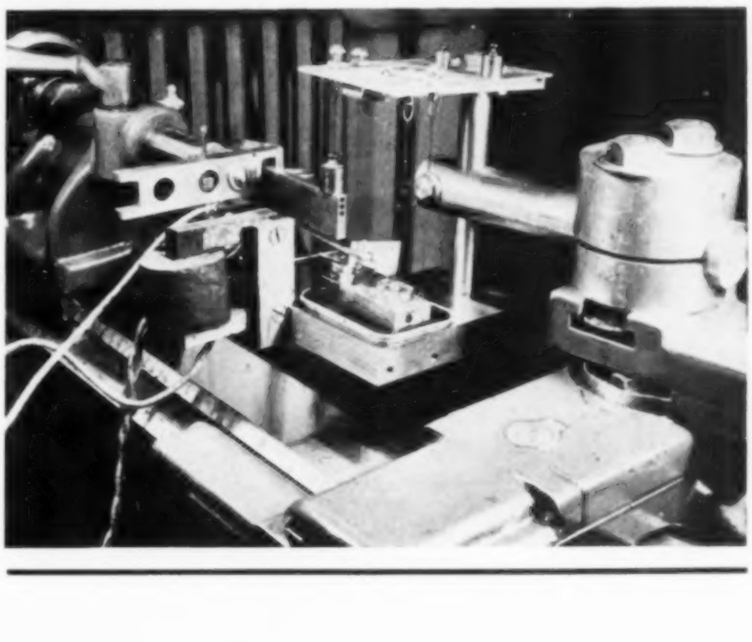
Other work has shown that the relative hardness as determined by the scratch method may vary for different loads on the diamond point. For this reason various loads were used in determining the energy required to scratch. The energy was then plotted as a function of the load and the results for several metals compared. Those requiring the greatest energy for removal of a unit volume of material should show the best resistance to sliding wear.

The work accomplished up to the present time has been very preliminary. Results are promising but the machine requires some refinements. However, the results of preliminary tests on two materials are included here in the hope that they will be of interest, and perhaps induce some comment on the method employed.

For the purpose of comparison, a piece of stellite and another of nitrided nitralloy were taken. Results obtained from the scratch test are given in the curves, which indicate that the latter requires more energy to remove unit volume of material. From this we may conclude that under conditions of sliding wear the nitrided nitralloy will be more satisfactory. From the wear tests that were made on these materials as described last month, this same relation was found to exist. When two pieces of nitrided nitralloy were rubbed against each other, the loss of weight was 3.4 $\times$ 10^{-8}g./in.^{2}/ft., while the stellite vs. stellite showed a loss of weight of 45.5 $\times$ 10^{-8}g./in.^{2}/ft., both tests under a load of 300 psi. and a sliding velocity of 786 ft. per min.

The curves shown herewith indicate that the two materials remain in approximately the same relative position as the load increases. Another material would not necessarily give a curve parallel to those shown, because the increase in energy for a given increase in load may not be the same for different materials.

In conclusion, the method described in this paper differs from the work of previous investigators in that the force required to produce a scratch is employed in conjunction with the width of scratch made by a diamond of known dimensions. Heretofore investigators have attempted to make some correlation between the width of scratch and the results of wear tests without success. Our preliminary tests have indicated that the energy method may give results which are correlative with the wear resistance, and it is our hope that this paper may bring about some discussion and further investigation.



Valve Rocker Arms and Silencer Mechanism on Cadillac Engine; Photographed by Anton Bruehl

APPRAISING A STEEL FOR A GIVEN DUTY

By A. L. Boegehold
Head, Metallurgical Dept.
Research Laboratories Section
General Motors Corp.

IN A PAIR of articles in the February and March issues the properties of plain carbon steels which interfered with wider use in important machine parts, were contrasted with the corresponding properties of alloy steels. In view of the facts that numerous alloy steels are in use for the same automotive part —a situation which involves needless expense —and that new alloys are continually being promoted, it will be well to conclude with a discussion of the methods which we have found useful in appraising the utility of the commonly used steels for this or that part, and the types of information we would like (but can get with difficulty, if at all) concerning new steels proposed as substitutes.

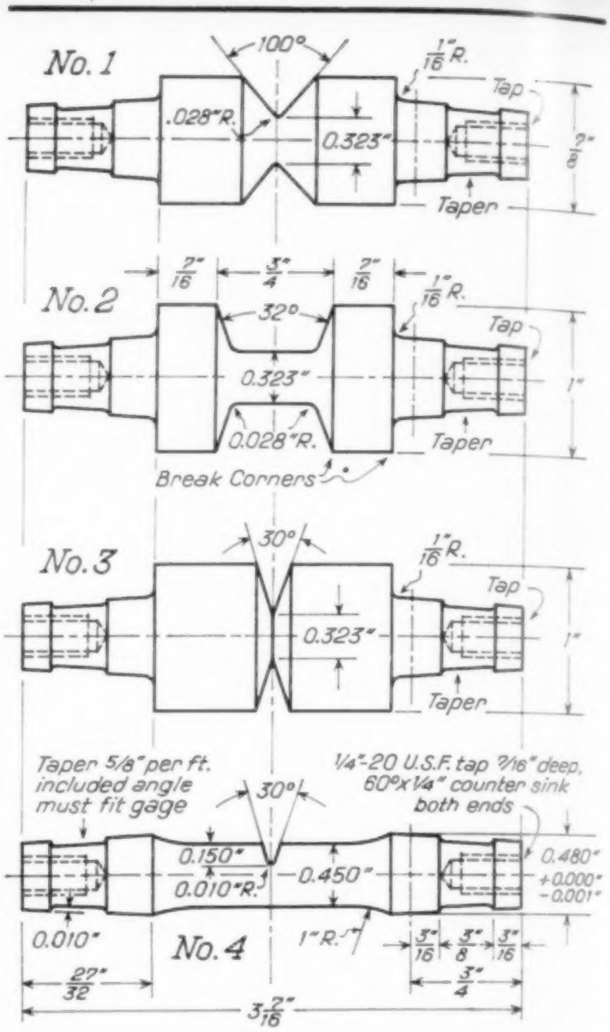
If we were given the job of substituting cheaper or better steels for those now being used for automobile parts, how would we determine whether the proposed steels would be satisfactory for the part? If there were only one steel to investigate, the obvious course would be to make some of the parts in question from the new steel, put them in cars and test them. This procedure is expensive and sometimes the money is not forthcoming, unless there is some evidence indicating that the proposed steel has a good chance of giving a satisfactory account of itself. If there are several steels to investigate, then the cost of testing in cars becomes excessive.

The next best course is to make car parts from the new steel and build a testing machine to test these parts under conditions as near service as possible. This is a fairly reliable procedure and good results can be obtained. For parts like gears where each new steel and heat treatment produces a different change in shape during heat treatment, the results are obtained very slowly. Many experiments must first be performed with each steel to find the shape to which the gear teeth must be machined so that after each proposed heat treatment they are near enough the shape of teeth on the other gears in the test for comparable tooth loading.

On account of the difficulties, expense and slowness of obtaining the desired information by means of tests on actual parts, many attempts have been made to interpret the mechanical tests on various kinds of specimens. There have even been attempts to use simply the tensile test for this purpose. Of course, the tensile test is valuable for investigating the uniformity of steel from heat to heat, and the specification of a "merit index" consisting of the product of the tensile strength and the reduction of area is a satisfactory way for insuring a uniform quality of consecutive shipments of steel

used in production. Other merit indexes have been suggested in the past, such as elastic limit times elongation, tensile strength times Izod impact, and a figure derived from the following formula: ½ (tensile strength + elastic limit) × elongation ÷ (100 − reduction of area). A steel which has already been tested and proved satisfactory in some car part may be gaged by some merit index, like those just mentioned, and as long as succeeding shipments of the same specification of steel meet the merit index requirement, it can reasonably be expected to respond normally to processing treatments and to function satisfactorily in service.

It does not follow, however, that some other steel having just as high a merit index will be suitable for the same part, or that a steel with a higher index will have a longer life in that part. The reason for this is that the stresses in a tensile test specimen are not similar to the stresses in a single important part of an automobile. Furthermore, the merit index obtained by means of a tensile test is expressed in values that are a function of a type of failure which does not occur when automobile parts fail (excepting when the car hits a telegraph pole). The tensile test specimen does not break until it has elongated and become smaller in diameter at one point. Broken car parts, on the other hand, almost invariably show no elongation or reduction of area.



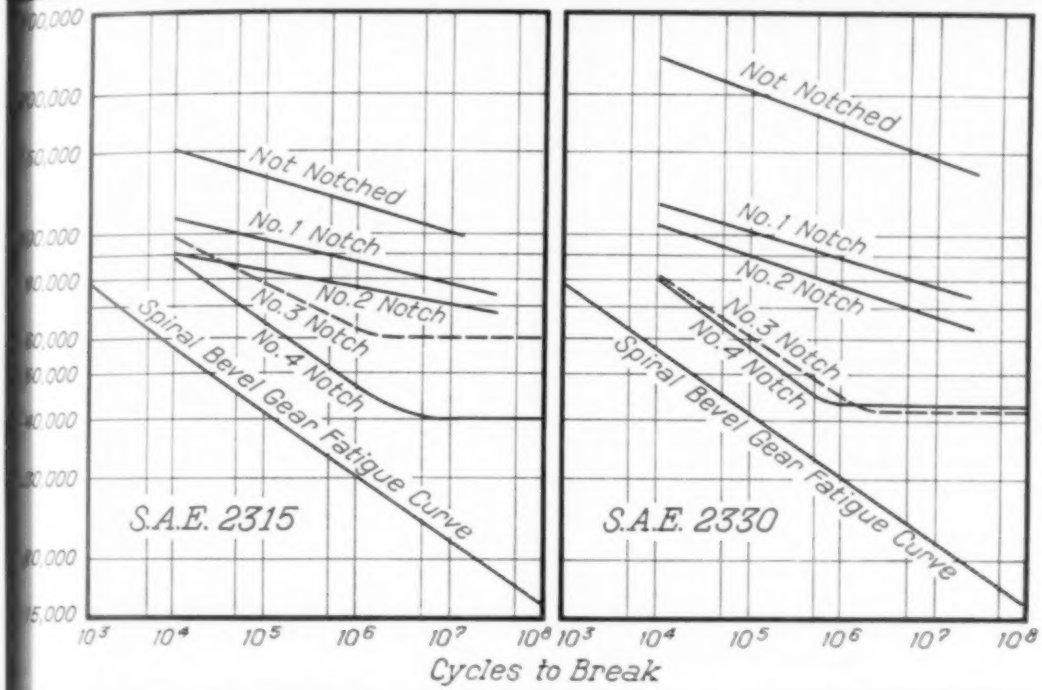
Round Test Bars for Determining the Effect of Various Types of Notches on the Endurance of Gear Steels

Strength at Notches

One variety of this kind of fracture is fatigue failure, caused by a large number of stress applications above the endurance limit but below the elastic limit. Being below the elastic limit there is no apparent flow of metal. Another variety of fracture results from a breaking stress applied at a notch, and fracture through a notch or groove will also occur without any manifestation of ductility. In order to make a ductile material break without any apparent ductility, all that is necessary is to machine a groove around it. Two tensile test specimens machined from the same bar of steel with the same diameter of 0.505 in. at the smallest point, the one having a 2-in. length of this diameter and the other having a diameter of 0.505 in. at the bottom of a notch machined around a larger bar, will break entirely unlike each other. The notched one will show 25 to 50% higher strength than the other, depending on the steel and the shape of the notch. This does not mean that the metal is any stronger; what it does indicate is that the calculation of tensile strength is arbitrary and may be misleading unless intelligently interpreted.

When a tensile test specimen necks down, the area at the reduced diameter may be only 40 or 50% of the original area of the test bar. While in this necked down condition, the test machine registers the load from which we calculate the tensile strength. But instead of calculating the tensile strength using the area at the reduced diameter present at the time the maximum load was recorded, it is calculated on the original area of the test section. This seems rather illogical to me. When the specimen noted above with an artificial notch or neck is tested in tension there is no reduction of area at the time the maximum load is recorded; therefore the maximum load is much higher since it is supported by an area considerably greater than that present at failure of the standard specimen which necks down. This higher load, when calculated to unit stress on the same area as for the standard test specimen, gives a higher quotient

Curves Below Represent the Relationship Between Endurance of Standard Rotating Beam Test Pieces, Spiral Bevel Gears Taken From Production, and Notched Test Pieces Sketched at Left. S.A.E. 2315 steel pieces were carburized 8 hr. at 1650° F., oil quenched from carburizing heat, reheated to 1330° F., oil quenched, drawn at 300° F. S.A.E. 2330 pieces were carburized 4 hr. at 1650° F., oil quenched from carburizing, reheated to 1375° F., oil quenched, drawn at 300°

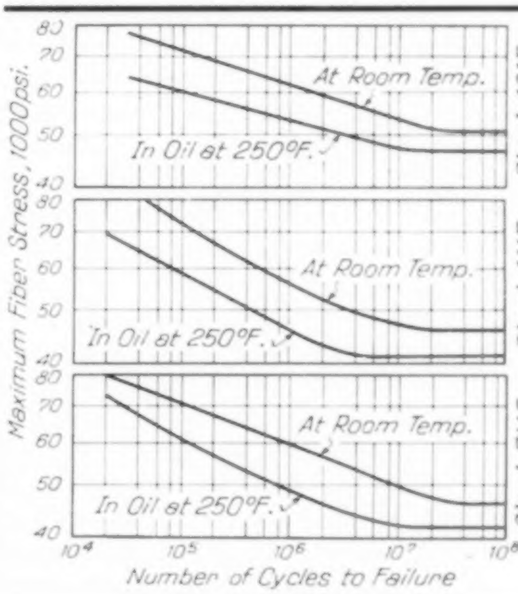


than when obtained with the standard tensile test specimen. It would seem that this higher figure would more nearly represent the ultimate strength of the material. If the tensile strength of the standard tensile specimen were calculated using the reduced area at the necked down section, the tensile strength would be much higher than with the conventional method and this figure would be higher than the one obtained by using the notched specimen, partially due to the hardening and strengthening of the metal at the reduced diameter where some cold working takes place.

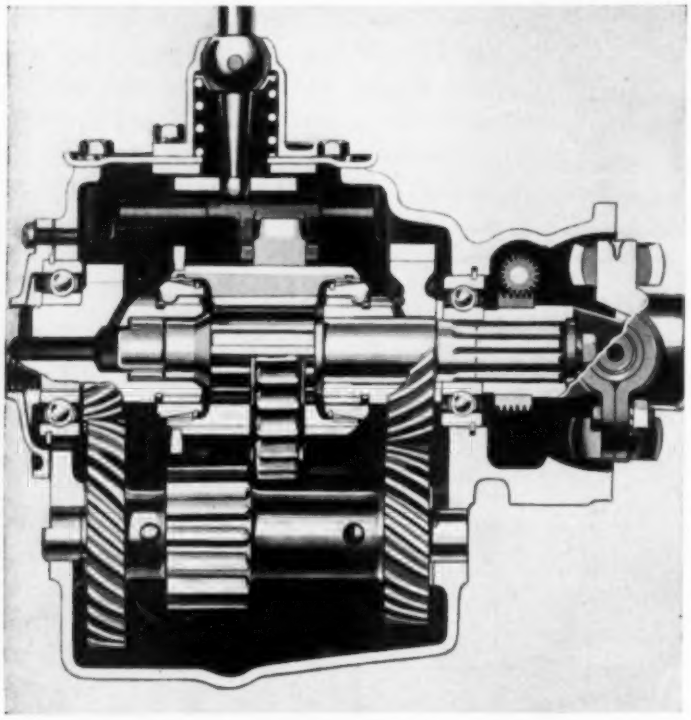
This difference in test results from differently shaped specimens may also be influenced by the kind of steel and its heat treatment. Stress concentration varies depending upon the size and shape of the notch; for the same notch it varies depending upon the steel used. Therefore it is very difficult to design a test specimen that will simulate the stresses that occur in the particular part in question.

At the General Motors Research Laboratory we have been investigating various methods for testing carburized and hardened steels in an attempt to find a test that would indicate the best material and heat treatment for rear axle ring gears and pinions. Tests have been made on square transverse test bars of various sizes, plain rotating beam fatigue specimens, several different types of notched rotating beam fatigue test specimens—all at room temperature—and finally a notched rotating beam test specimen at 250° F. So far an entirely satisfactory correlation with service results or with rear axle dynamometer results has not and possibly will not be obtained because of the distortion which occurs in gear teeth during heat treatment, which localizes the loads.

In the meantime we have obtained a lot of interesting information on how various notches reduce fatigue life and how temperature still further reduces it. Notes on some of this work were presented to the



Endurance of Gear Steels, Notched Specimens, Loaded Above the Fatigue Limit Is Reduced 90% Merely by Running Them in Common Lubricating Oil at 250° F.



🌑 convention in Cleveland last fall by the present writer. The first drawing on page 404 (taken from that paper) shows the types of specimens used and the curve sheet on page 405 compares the endurance of plain rotating beam fatigue test bars with these other bars.

On account of space limitations the results on only two grades of 3½% nickel steel, carburized, can be presented. Taking as a criterion the stress at which failure occurs in 800,000 applications, the curves for S.A.E. 2330 show that the plain test bar will stand up under 177,000 psi., whereas the same steel in the same condition except that it has a No. 4 notch will only withstand 52,000 psi. The effect of stress concentration is to divide the safe load by 3.4. The corresponding figures taken from the stress-cycle curves for S.A.E. 2315 (left of the pair on page 405) are 117,000, 45,000 and 2.6 respectively. It will be noted that the strength of these two steels, essentially alike except for carbon content, is affected differently by the same notch. The endurance of the higher carbon 2330 steel after carburizing and heat treating is decreased a great deal more by notches than is the 2315 steel in the same condition.

Various heat treatments also have their effect. The stress-cycle curves for S.A.E. 2315 are for a quench from the pot, a second quench from 1330° F., and a 300° draw; as above noted the effect of stress concentration at No. 4 notch is 2.60. If this same carburized steel is transferred from the carburizing pot to a furnace at 1375° F. until it cools at that temperature, then quenched in oil and drawn at 300° F., the stress concentration at No. 4 notch is not 2.60 but 2.47. Likewise if the test bars are quenched from the pot and drawn at 300° F., the stress concentration at No. 4 notch jumps up to 2.77.

The last set of three curves (bottom of preceding page) shows the effect of notches. Heat treatment of the specimens was as follows: The nickel-molybdenum steel S.A.E. 4615 was carburized 9 hr. at 1675° F., quenched from the carburizing heat in oil at 100° F., and drawn 30 min. at 300° F. The nickel-chromium steel S.A.E. 3115 and the chromium-molybdenum steel S.A.E. 4115 were heat treated by the above program except that carburization was 8 hr. instead of 9 hr.

The upper curve in each of the three pairs represents the endurance of the material tested at room temperature, using a notched rotating beam specimen, while the lower curve gives the endurance of the same material run at a temperature of 250° F. in contact with lubricating oil.

The decrease in fatigue endurance limit is in the neighborhood of only about 8%, but at stresses above the endurance limit (which are what we have to consider in determining the life of rear axle gears) the number of stress applications at a given stress that can be endured without failure when tested at 250° F. is only about one-tenth that which is obtained when tested at room temperature!

Required Data on New Steels

With a realization of how many factors influence the application of steel to the automobile, I will conclude by offering a list of the various classes of information we desire about the steels we now have, and about the steels we want developed to render the same service but at a lower cost:

1. Endurance tests to determine the effect of section size in connection with different shaped notches.

2. Critical quenching speeds of all steels or depth hardening ability in any size section.

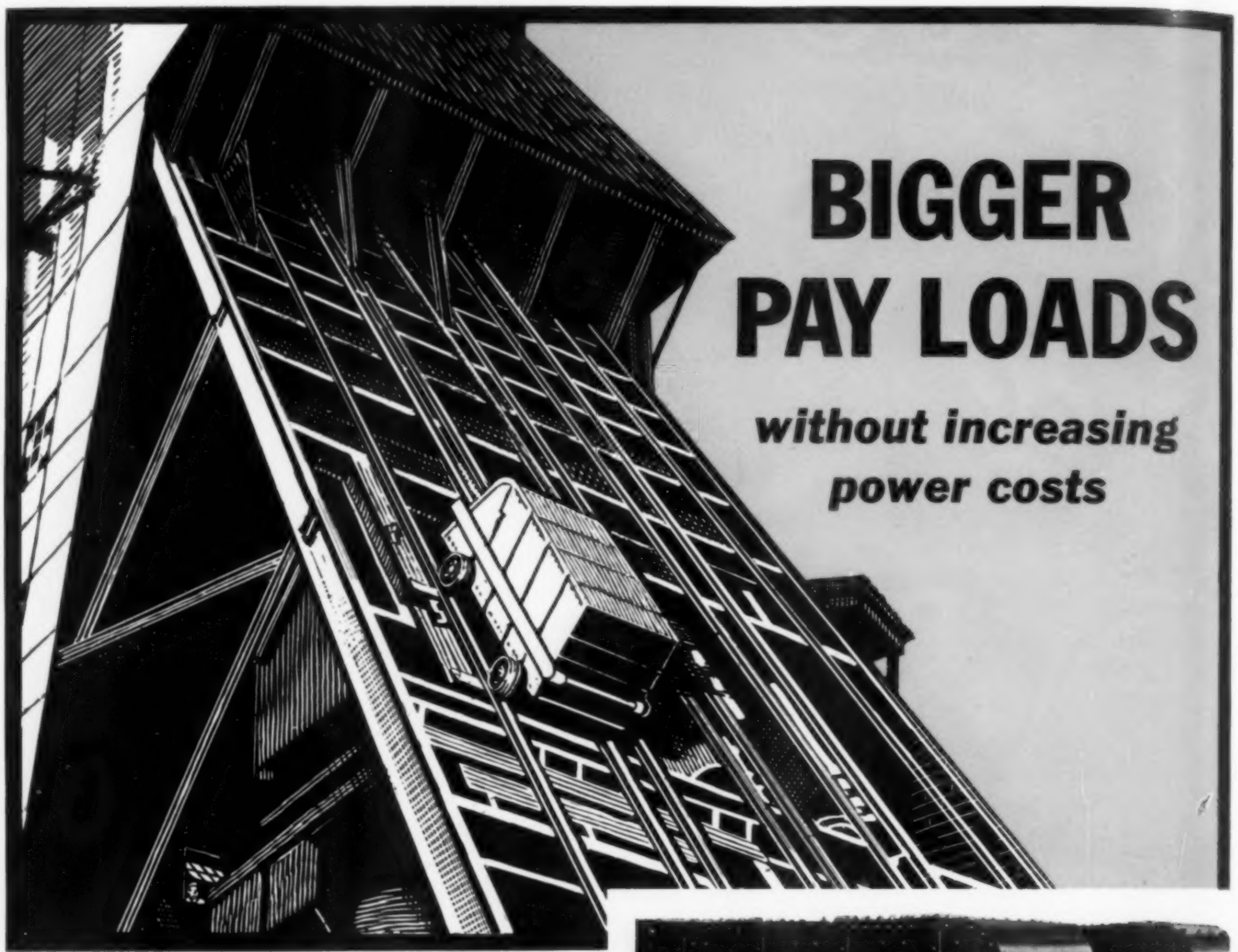
3. Method for gaging the tendency to distortion.

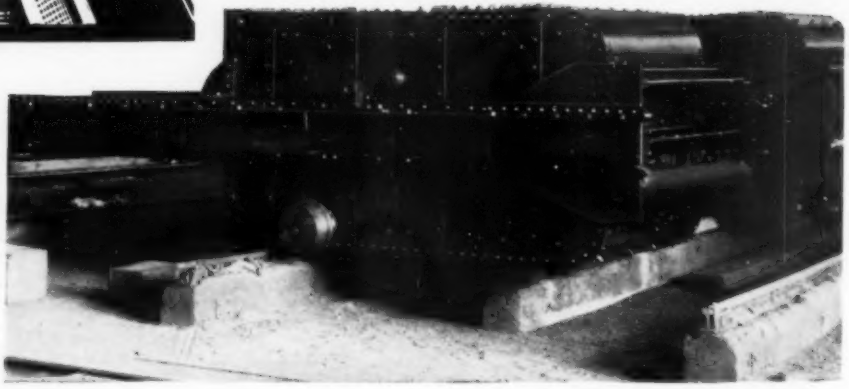
4. Machinability at various hardnesses.

General Requirements and Nickel Alloy Steels Used in Oil Production Equipment

Adapted from a paper presented by A. G. Zima before American Petroleum Institute, Tulsa, Okla., May 1936 meeting.

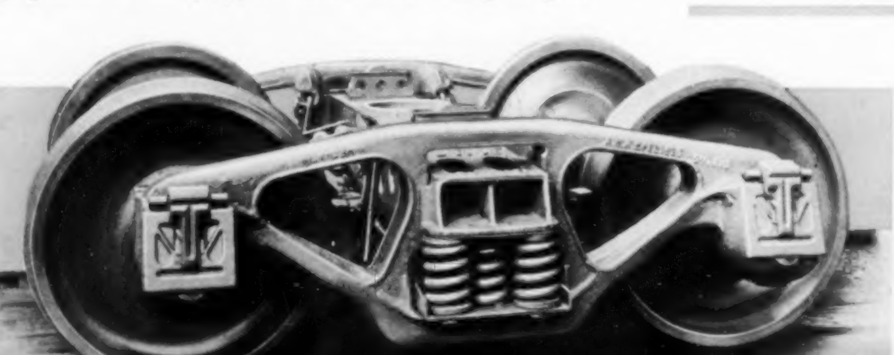
PARTS	High Yield Strength in: Tension	Bending	Compression	Torsion	Shear	Resistance to: Fatigue	Shock	Wear	Galling or Seizing	Corrosion Fatigue	Depth of Hardening	STEELS HAVING THESE PROPERTIES
Drilling tools and accessories												
Bit bodies	--	--	--	--	√	√	√	--	√	--	--	Cast nickel-chromium and nickel-molybdenum steel
Bit and reamer cutters	--	--	--	--	--	--	√	√	--	--	--	S.A.E. 3115, 4615, 2315
Cutter pins	--	--	√	--	√	--	--	√	--	--	--	Carburized S.A.E. 3115, 4615, and 2315; Also oil hardened S.A.E. 3250, 4650, 3340
Reamer bodies	--	--	--	√	--	√	--	--	√	--	√	S.A.E. X-3140; S.A.E. 3140; cast nickel alloy steel
Drill collars	√	√	--	√	--	√	--	--	√	--	√	S.A.E. X-3140; also S.A.E. 3140
Kellys	√	√	--	√	--	√	--	--	√	--	√	S.A.E. X-3140; also S.A.E. 3140
Tool joints	√	--	--	√	√	√	--	--	√	√	√	S.A.E. X-3140; also S.A.E. 3140
Fishing taps and dies	√	--	√	--	√	--	--	√	--	--	--	Carburized S.A.E. 3115, 4615, 2315
Slips	√	--	√	--	√	--	√	√	--	--	--	Carburized S.A.E. 3115, 4615, 2315
Rotary chain												
Side bars	√	--	--	--	--	√	√	√	--	--	--	S.A.E. 3135, 3140
Connecting pins	--	√	√	√	√	√	√	√	--	--	--	Carburized S.A.E. 2512 or oil hardened S.A.E. 3245
Bushings	--	--	√	--	--	√	√	√	--	--	--	Carburized S.A.E. 2320
Draw-works												
Shafting	--	√	--	√	√	√	√	--	--	--	√	S.A.E. X-3140, 3245, 3140
Brake rims	√	--	--	--	--	--	--	√	√	--	--	Cast nickel alloy steel
Brake bands	√	--	--	--	--	--	--	--	--	--	--	High carbon nickel-molybdenum steel
Sprockets	√	--	--	--	√	√	√	√	--	--	--	Cast nickel alloy steels
Rotary machines												
Shafting	--	√	--	√	--	√	--	--	--	--	√	S.A.E. X-3140, 3245
Gears	--	--	√	--	√	√	√	√	--	--	--	Carburized S.A.E. 2315, 2512, or oil hardened S.A.E. 3245
Crown and traveling blocks												
Bearings	--	--	√	--	--	√	√	√	--	--	--	Carburized S.A.E. 3115, 4615
Pins	--	√	√	--	--	√	√	√	--	--	--	Carburized S.A.E. 4615, 3130
Sheaves	--	√	√	--	--	√	√	√	--	--	--	Cast nickel alloy steel
Rotary swivels												
Bearings	--	--	√	--	--	√	√	√	--	--	--	Carburized "Krupp analysis"
Bail bolts	√	--	--	--	--	--	√	--	--	--	--	S.A.E. 3245
Slush pumps												
Piston rods	--	√	--	--	--	√	√	√	√	--	--	S.A.E. 3140, 3150, 2325, or carburized S.A.E. 4615
Valve bodies and seats	--	--	√	--	√	√	√	√	--	--	--	Carburized S.A.E. 4615, 3115
Cylinder liners	--	--	--	--	--	--	--	√	--	--	--	Carburized S.A.E. 4615
Well-control equipment												
Blow-out preventers	√	--	--	--	--	--	√	--	--	--	--	Cast nickel alloy steels or forged S.A.E. 3140
Drilling valves	√	--	--	--	--	--	√	--	--	--	--	Cast nickel alloy steels or forged S.A.E. 3140
Control valves	√	--	--	--	--	--	√	--	--	--	--	Cast nickel alloy steels or forged S.A.E. 3140
Bolts and studs	√	--	--	--	√	--	√	--	--	--	--	S.A.E. 3140, 3240, 2330
Sucker rods	√	√	--	--	--	√	--	--	--	√	--	S.A.E. 3120, 3130, 4615





● This sturdy Nickel Alloy Steel ore carrier, weighing 12,000 lbs. unloaded, has replaced a carbon steel skip weighing 15,000 lbs. The saving of 3000 lbs. in dead-weight has been translated into greater pay load capacity, raising the hoisting capacity from 19,000 lbs. to 22,000 lbs. without increasing power costs. The high strength-weight ratio of the Nickel Alloy Steels, combined with their unusual toughness, make it possible to increase the capacity of haulage equipment of many types without increasing weight.

NICKEL ALLOY STEELS



● The side frames and bolster castings of this hopper car truck were made of Nickel Steel, effecting a saving of 20% in the weight of trucks without decrease in the required properties of strength and toughness. Our engineers will be glad to consult with you and to suggest how the Nickel Alloy Steels will save you money.

THE INTERNATIONAL NICKEL COMPANY, INC., 67 WALL ST., NEW YORK, N. Y.

DEVELOPMENTS IN GRAPHITIC STEEL FOR TOOLS & DIES

By F. R. Bonte and Martin Fleischmann
Steel and Tube Division
The Timken Roller Bearing Co.
Canton, Ohio

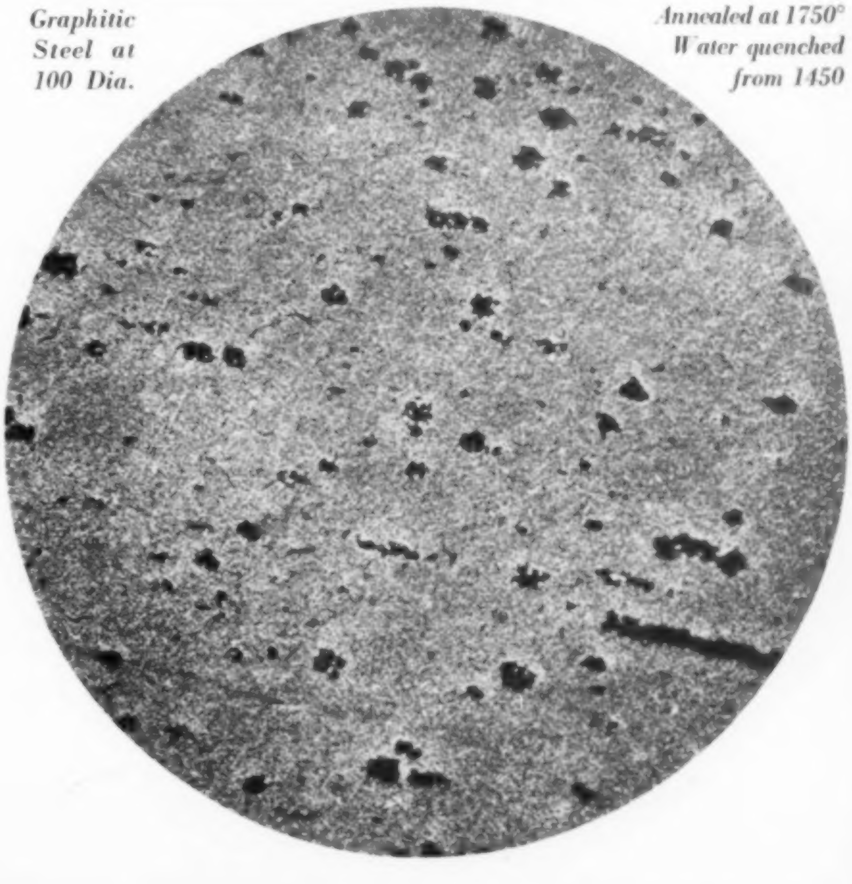
NEED FOR MATERIAL combining the advantages of cast iron and steel has long been apparent. Gray cast iron is noted for high resistance to wear and good frictional properties as well as its relative ease of machining. These advantages may be traced in a large degree to the presence of free graphite in this material. Further, it is the opinion of many metallurgists that cast iron possesses inherent damping properties superior to steel. However, the uniformity of steel, the ease with which it may be worked either hot or cold, its ready response to heat treatment and good physical properties, as compared to cast iron, have combined to increase and extend its application.

Much study and experimental work has been devoted to the development of a material combining the free machining and resistance to wear of cast iron with the response to heat treatment and forgeability of steel. Graphitic steel, which is a high carbon steel in which part of the carbon is present in the form of graphite, apparently possesses these qualifications to a marked degree.

As is the case in gray cast iron, the silicon content of graphitic steel is the controlling factor in the precipitation of free graphite. This fact has been well established in the production of gray cast iron and today silicon is the element most commonly used to control graphitization. However, in the production of graphitic steel, the silicon content must be held within definite limits.

The lower limit may be defined as that point at which the graphitizing effect of silicon is so weak as to require the use of excessively high annealing temperatures. This is clearly shown in the first graph, which indicates that the use of less than 0.50% silicon would neces-

Graphitic Steel at 100 Dia.

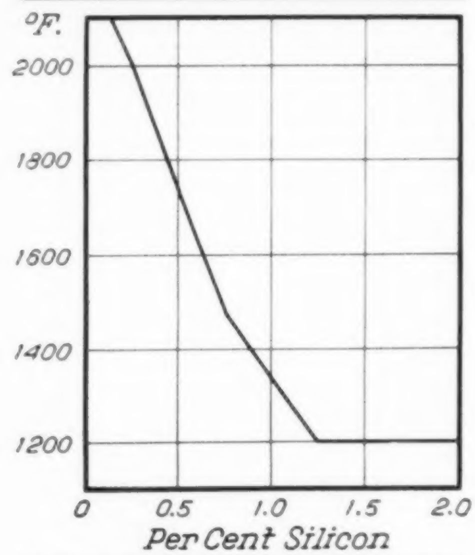


Annealed at 1750° Water quenched from 1450

sitate annealing temperatures considerably above those commercially and economically practical. Where carbide forming elements such as manganese and chromium are present, more silicon must naturally be added to the alloy steel to counteract their effect and insure precipitation of sufficient graphite.

The upper silicon limit may be considered as the point at which this element forms excessive graphite in the ingot, causing difficulty in hot working. In either case, ingot size and stripping temperature play an important part in the successful production of graphitic steel, for heat treatment will not restore forgeability to the steel if an excessive amount of free graphite has once been precipitated.

As now produced by the Steel and Tube Division of Timken Roller Bearing Co., approximately 1% of silicon is being used in the production of the graphitic steel known as "Graph-sil," which corresponds in use to the water hardening grade of die or tool steel. No difficulty is experienced in rolling or forging this type of steel, and it has been rolled elsewhere in strip form. The first micro (page 411) shows this material as rolled. It is a hyper-eutectoid steel composed of pearlite and free cementite with the possible appearance of small amounts of finely divided free graphite.



As Amount of Silicon Decreases the Temperature at Which Graphite Starts to Precipitate Increases Sharply. After Charpy and Grenet. The steel under experimentation had moderate amount of carbide formers (0.30% manganese)

The carbide phase is unstable because of the high silicon content of the steel and consequently may be easily changed by heat treatment. The table of physical properties on page 412 shows the different effects of air cooling and furnace cooling on the amount of combined carbon in the structure. Combined carbon decreases from about 0.60% to as low as 0.25% with an increase in temperature when the steel is furnace cooled. On the other hand it increases slightly if the material is air cooled (from about 0.65 to 0.75% as the annealing temperature goes up from 1400 to 1700° F.). The time at heat after the samples had reached a uniform temperature apparently does not change the combined carbon to an appreciable extent.

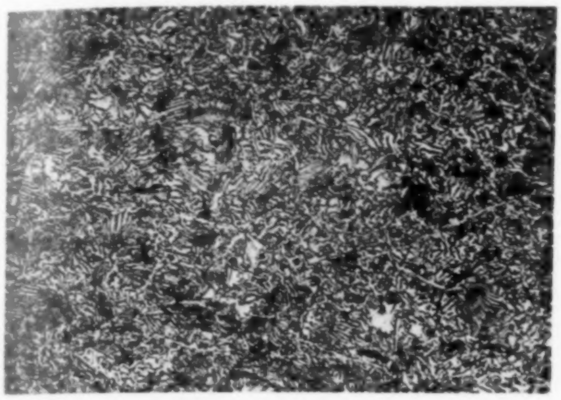
The structural effect of full annealing of this new material "Graph-sil" from 1750° F. is shown in the second micro, which clearly shows the free graphite surrounded by ferrite and the lamellar pearlite typical of a simple steel which has been cooled slowly from a relatively high temperature.

This accords with the established equation

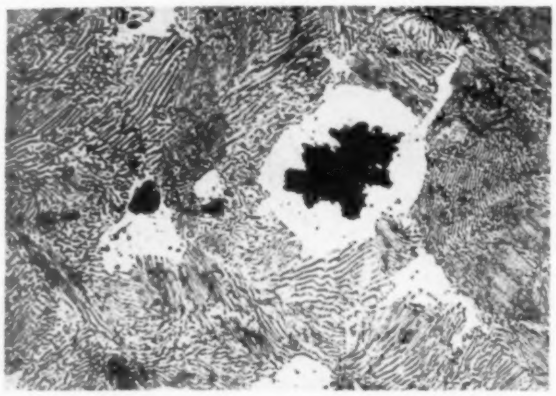
$$Fe_3C \rightleftarrows 3\ Fe + C$$

The cementite breaks down into ferrite and free graphite. Chemical determination of the combined carbon shows that such fully annealed graphitic steel is of a hypo-eutectoid composition — combined carbon always less than 0.90%. The degree of graphite precipitation is controlled in a large measure by the annealing treatment and it must be remembered that once the graphite has been precipitated the graphitic areas or pockets are established permanently. Even though the free graphite is later re-dissolved from these areas or microscopic pockets, voids remain in the finished product, serving as retainers for lubricant and thus functioning to prevent scoring and excessive wear in service.

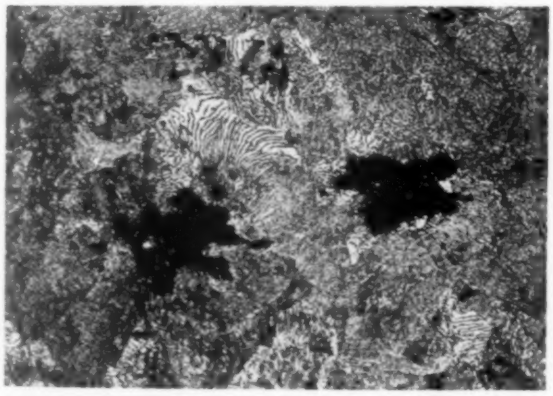
Normalizing this fully annealed material from 1550° F. re-dissolves part of the graphite, the equation $Fe_3C \rightleftarrows 3\ Fe + C$ being reversible. The structure developed by normalizing a piece of fully annealed graphitic steel is shown in the third micro. It will be noted that the combined carbon in the body of the steel has been increased to approximately the eutectoid value (analysis shows 0.90% combined carbon) and that the structure is very similar to that of a normalized eutectoid tool steel, having a dense pearlitic grain, except that it contains more or less free graphite. It is interesting to note on low magnification of a larger field that the number and size of the graphitic areas or pockets has not been changed substantially, even though the combined carbon is more than twice as great as when in the fully annealed condition. This can be explained by the logical assumption



As Rolled; Combined Carbon (C.C.) 1.20%, Graphite 0.28%



Rolled Bar, Annealed at 1750° F., Furnace Cooled. Combined Carbon (C.C.) 0.38%, Graphite 1.10%



Annealed Bar, After Normalizing From 1550° F. Combined Carbon (C.C.) 0.90%, Graphite 0.58%

that the dark areas are either partially empty or are complete voids.

When annealed "Graph-sil" is normalized and again annealed at 1400° F. the combined carbon is slightly reduced, as compared with a normalized sample, but the pearlite typical of the normalized condition has been spheroidized to the degree commonly associated with good machining qualities. The fourth micro illustrates this structure. Again the typical voids will be noted, apparently unchanged as to number and average size. Experience indicates that graphitic steel in this condition machines in much the same manner as does gray iron, which effects a saving in machining time of approximately 50% as compared with other water hardening or oil hardening tool steels.

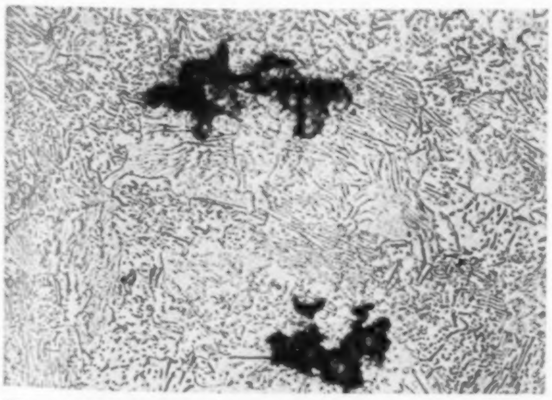
Quenching graphitic steel from above the carbon change point after the graphite has been precipitated develops a martensitic structure, retaining the characteristic voids established by the graphite, the material reacting in a manner similar to that exhibited by a eutectoid tool steel. The fifth micro is a typical structure so obtained by quenching in water from 1450° F. File hard surfaces, exceeding C-60 on the Rockwell scale, are readily secured and the hardened material may be tempered as desired.

Physical properties of graphitic steel are of course closely related to the microstructures, which in turn depend upon the heat treatment and the resulting combined carbon. A typical set of values is given in the table on the next page.

Experience has demonstrated that we have no difficulty in hot rolling or forging our graphitic steel. Forging temperatures should not, however, exceed 2000° F. This steel may also be welded satisfactorily, but it will air harden and consequently should be normalized or annealed after welding to relieve internal strains and restore the microstructure. Cold

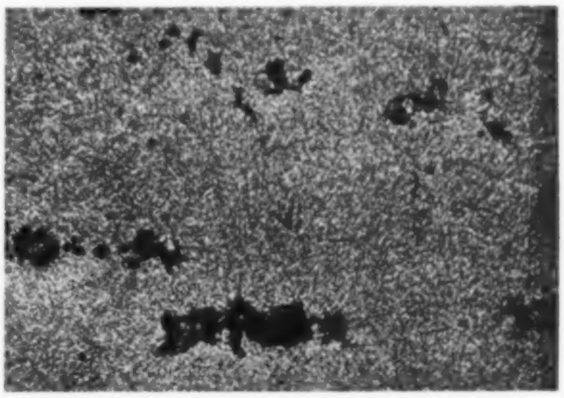
Microstructure (500 Dia.) of Graphitic Steel in Various Stages

Analysis: 1.48% C, 0.40% Mn, 0.012% P, 0.016% S, 0.90% Si



Annealed and Normalized Bar, After Spheroidizing at 1400° F. C.C. 0.73% Graphite 0.75%

Annealed at 1750°, Water Quenched From 1450° F. C.C. 0.78% Graphite 0.68%



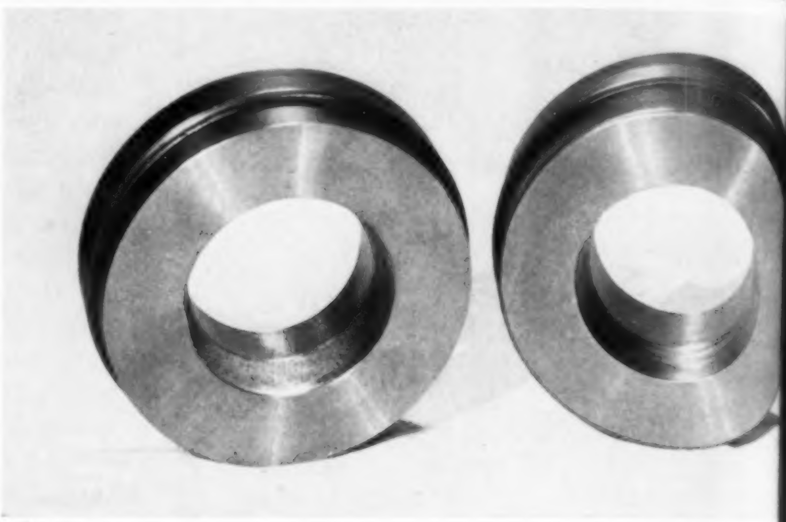
forming is somewhat limited, as the relatively large amount of free graphite materially decreases its ductility. However, a considerable degree of improvement in ductility may be obtained by cold drawing and subsequent low temperature annealing. A $\frac{7}{8}$-in. cold-drawn "Graph-sil" bar can readily be bent cold 180° around its own diameter after the following treatment: Hot-rolled to 1-in. round; annealed at 1800° F., furnace cooled; pickled to remove scale; cold-drawn in two passes to $\frac{7}{8}$-in. round; annealed at 1250° F. for 1 hr.

Service Data Acquired

Service data on a wide range of dies made from graphitic steel indicate a life of from two to ten times that of the carbon or alloy steel or cast iron formerly used. This experience extends over at least a year in Timken Roller Bearing Co.'s plants and in those of several cooperating firms.

"Graph-sil" has also been used successfully in various types of gages, centerless grinder blades and grinding spindles. A considerable degree of acceptance has likewise been developed for this material for cylinder liners and sleeves for gasoline and diesel engines, because of its free machining qualities and the fact that a sleeve made from graphitic steel tubing need be only $\frac{1}{16}$ in. thick.

Other applications proven successful in preliminary service tests include bushings, brake drums, air hammer pistons and guides, and piston rings. In all these applications the free machining qualities, ability to develop a high hardness, long life and the positive lubrication assured by the graphitic areas or oil absorbed in the voids have demonstrated their economic and technical value.



Sizing Die Made of Conventional Steel Scuffed After 10,000 Pieces, Another of Water Hardening Graphitic Steel Is in Good Shape After

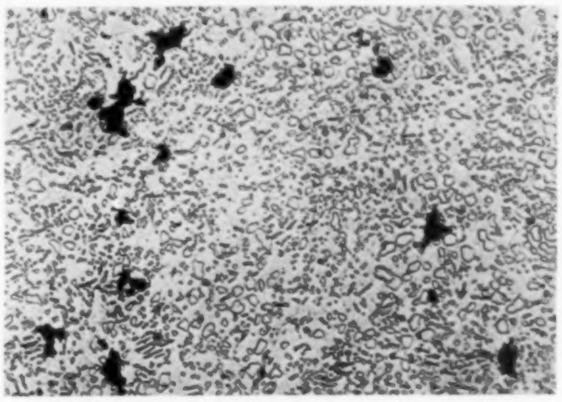
The drawing die shown at the left of the pair was made from a standard grade of water hardening die steel. It was used for sizing Timken bearing cages. Service records show that after sizing approximately 10,000 pieces, dies of this type are badly scuffed, as shown in the illustration. When "Graph-sil" was used in this same design and service, however, a run of 309,000 pieces was made and the die still remained in good condition! This is shown at the right in the illustration. The hole in this die was quenched in a water spray from 1500° F. and the piece tempered at 300° F.; the wearing surface developed a hardness of C-62 to 63, Rockwell, while the body of the die showed C-20 to 22.

Physical Properties of Graphitic Steel

Analysis: 1.51% C, 0.96% Si, 0.40% Mn, 0.015% P, 0.014% S

Treatment	Combined Carbon	Yield Point	Ultimate Strength	Elong. in 2 In.	Red. of Area	Brinell	Izod Ft.-Lb.
Specimens Air Cooled From Respective Annealing Temperatures							
1400° F.	0.66	62,250	120,250	17.5	26.1	241	8.0
1500° F.	0.69	65,500	138,500	13.5	20.3	255	7.0
1600° F.	0.72	67,500	143,000	12.0	17.4	269	4.5
1700° F.	0.75	70,750	147,000	10.5	15.2	285	4.0
Specimens Furnace Cooled From Respective Annealing Temperatures							
1400° F.	0.59	47,250	97,000	23.5	38.6	197	18.5
1500° F.	0.55	47,700	99,000	19.5	29.9	201	15.0
1600° F.	0.48	50,000	100,000	18.0	22.0	201	10.0
1700° F.	0.26	44,000	81,000	15.0	21.8	163	10.0
Annealed Specimens Water Quenched From 1450° F. and Tempered as Shown							
900° F.	0.86	158,000	201,500	8.5	18.1	388	....
1100° F.	0.79	116,000	154,000	14.0	30.0	302	....

Graphitic Steel Containing 0.25% Molybdenum, Annealed, Normalized and Spheroidized. Combined carbon 0.75%, graphite 0.70%



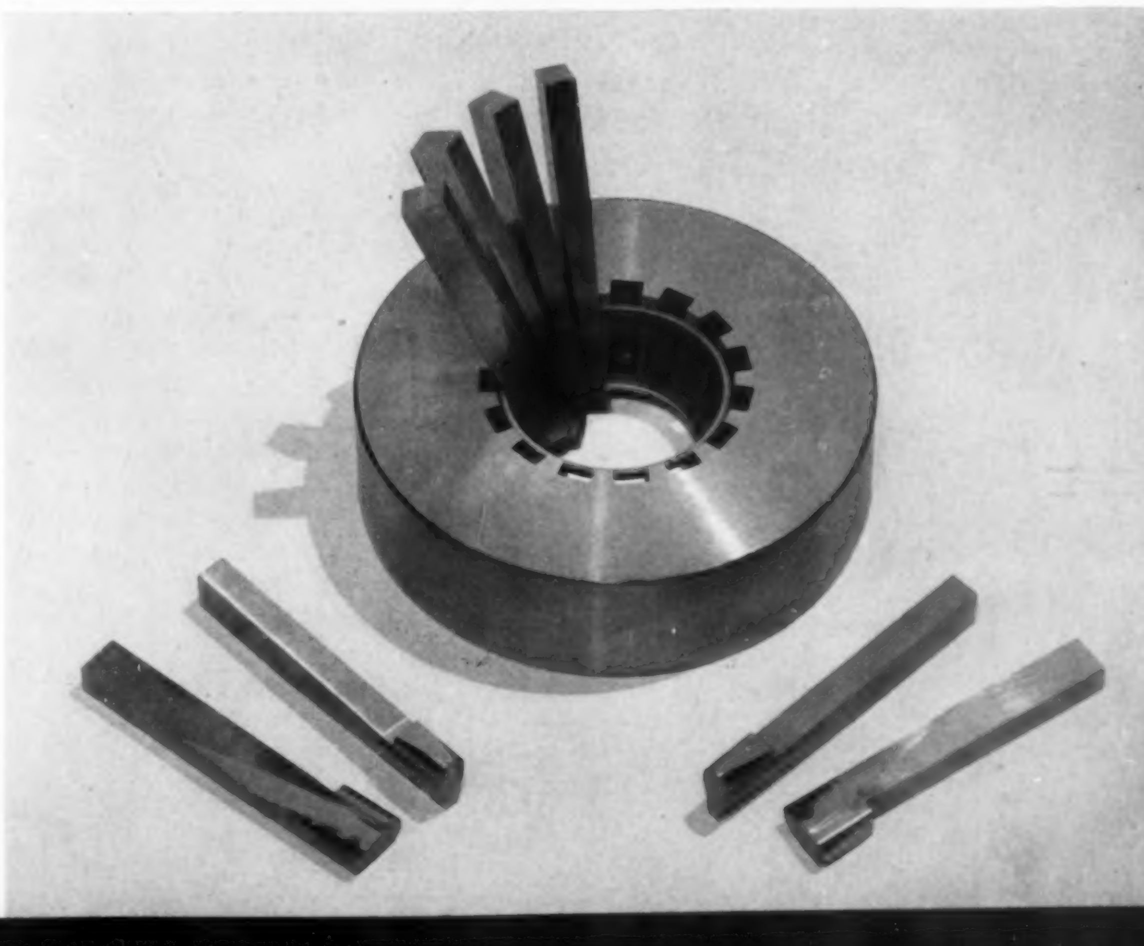
Alloy Graphitic Steel "Graph-mo"

A second type of graphitic steel has also been developed to meet the need for an oil hardening grade while still retaining the free machining properties of water hardening "Graph-sil," yet having improved physical properties together with minimum distortion when quenched in oil. This grade of graphitic steel has been designated as "Graph-mo" since it carries 0.25 to 0.30% of molybdenum. It has been used successfully in the Timken bearing factory and other plants for dies formerly made from oil hardening grades of tool steel. It responds to heat treatment in much the same manner as does "Graph-sil," and the last micro illustrates the typical structure of the steel as shipped ready for machining and hardening. After quenching it will closely resemble the microstructure of quenched "Graph-sil" as shown in the previous view. Its complete chemical analysis is 1.45% C, 0.35% Mn, 0.008% P, 0.015% S, 0.75% Si and 0.25% Mo.

A typical example of the use of "Graph-mo" for winging (coining) punches is shown in the halftone at the bottom of this page. Where formerly an oil hardening tool steel was used and gave a life of 1000 to 4000 pieces, the use of "Graph-mo" for the same part enabled 44,000 pieces to be made. These punches were quenched in oil from 1450° F. and tempered at 300° F., developing a hardness of C-61 to 62 without distortion. Service in the Timken bearing factory shows that the edges of punches made from this new material stand up in regular production work without showing any evidence of chipping, dulling or spalling.

Research on properties and characteristics of graphitic steel is still being conducted in the laboratories of the Steel and Tube Division of The Timken Roller Bearing Co., and test applications of both varieties described in this article are being studied in the bearing factory and numerous other plants. Considerable experience has already been accumulated on their service as dies for working and shaping materials such as steel, brass, Dow metal, aluminum, paper and powdered bronze. Although much work still remains to be done to determine accurately the best methods of handling and applying graphitic steel, the data at hand indicate a wide range of potential possibilities.

Oil Hardening Graphitic Steel in Coining Die and Punches in Good Shape After Ten Times the Average Production of Dies Made of Conventional Steels. Bearing cage is shown in die; a series of 15 punches are arranged in a circle (of which four are in place) and a tapered plug forces their enlarged lower ends into the slots



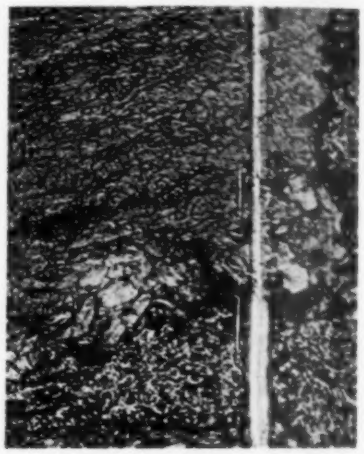
Nitrogen Absorbed by Steel When Lubrication Fails

Special letter to Metal Progress
By Hans Diergarten
Metallurgist, SKF Bearing Co.

Schweinfurt, Germany — It was demonstrated some years ago by M. Fink that steel parts rubbed together dry will develop a peculiar surface condition leading to rapid fatigue failure. This is not, however, a purely mechanical problem, since the chemical effect of "friction oxidation" also plays a part. This "friction rust" at points of contact, such as on axle journals, for instance, not only causes the red oxide, rust, but fatigue failure frequently starts from these spots. A. Thum and F. Wunderlich, on the other hand, believe that oxidation plays only a subordinate role to mechanical effect. They base this view on tests of S. J. Rosenberg and L. Jordan indicating that more wear and surface roughening take place in an oxygen-free atmosphere than in one containing oxygen.

A Section Through a Spring Leaf Shows That Bright Worn Spots on the Surface Are Associated With a Structureless Micro-Constituent. This and other views are kindly loaned by H. Schottky and H. Hiltenkamp of the Krupp laboratories

H. Schottky and H. Hiltenkamp have studied several parts that had been worn smooth (and their work is reported in *Technischen Mitteilungen Krupp*, 1936, No. 3) in order to determine why fracture originated at these spots. They found no rust on these spots, and came to the conclusion that nitrogen, not oxygen, was the important factor in the destruction of the surface by wear. The following notes endeavor to summarize this important investigation.



Diamond Scratch Test Shows Relative Hardness of Material Developed at Worn Spots Compared With Cold Worked Steel Below

The first micrograph shows a longitudinal section through a bright spot worn smooth on a spring leaf. A change in structure at the surface is obvious. Numerous cracks are also present. It can be seen that the hard material of the outer layer has pressed into the intermediate layer and caused it to deform. The hardness of this new structure in the outer layer is shown by the scratch hardness test. Similar observations have been made on other test pieces.

The supposition that these spots are enriched in nitrogen was confirmed by micro-chemical investigations by P. Klinger and W. Koch. The nitrogen content of the worn spot was 0.074 to 0.090%, while the surface below this spot contained 0.0065% and the interior of the piece contained 0.006%. These values were obtained on chips scraped from the spring.

Similar observations were made on damaged gear teeth. This steel had 0.40% carbon. A section normal to the surface shows that a layer of special constituent exists down to a definite depth, and sections parallel to the surface show bright islands of this special constituent embedded in a ferritic-pearlitic groundmass. Micro-chemical nitrogen determination on the highly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A BRAND-NEW CUSTOMER used the telephone this morning. Betty Sue called up that nice little girl around the corner.
Every day, hundreds of Betty Sues speak their first sentences into the telephone. Just little folks, with casual, friendly greetings to each other. Yet their calls are handled as quickly and efficiently as if they concerned the most important affairs of Mother and Daddy. For there is no distinction in telephone service. Its benefits are available to all — old and young, rich and poor alike. To Betty Sue, the telephone may some day become commonplace. But it is never that to the workers in the Bell System.
There is constant, never-ending search for ways to improve the speed, clarity and efficiency of your telephone calls . . . to provide the most service, and the best, at the lowest possible cost.
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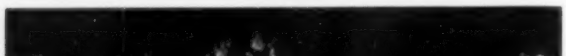
stressed part at a worn spot and on an unscored section near by, subjected to less stress, gives the following values:

	Highly Stressed	Less Stressed
Thickness of surface layer	0.040 mm.	0.045 mm.
Nitrogen in surface layer	0.013%	0.008%
Nitrogen in interior	0.004%	0.004%

Another example was a chromium-nickel steel pinion in which chips scraped from the rubbed spot contained 0.042 and 0.035% nitrogen, while the interior contained 0.0065 and 0.006% nitrogen.

Similar conditions can be developed during wear tests on a shaft broken in fatigue originating in a worn area. Such tests at the Krupp laboratories showed an increase in nitrogen up to 0.12% for a specific surface pressure and temperature.



Special Structural Constituent Formed on a 0.40% Carbon Steel Gear, Badly Scoured and Pitted by Running Unlubricated

Chipping the surface likewise absorbs nitrogen from the air, which is an important factor in determining nitrogen in steel chips. In the same issue of *Technischen Mitteilungen Krupp* H. J. Wiester established the interesting fact that grinding soft iron can also cause the absorption of nitrogen. His test results show coarse grinding can increase nitrogen content to 0.09% in a material whose original nitrogen content was only about 0.01%.

Hans Diergarten

Multiple Tempering of High Speed Steel

Special letter to Metal Progress

By Francis W. Rowe

Metallurgist, David Brown & Sons, Gear Makers

Penistone, Sheffield, England — In the May issue of last year a letter was printed describing an investigation by Russian metallurgists on the multiple tempering of various high speed steels, which caused the writer to look up work done in his laboratories in 1933 on the same subject. At that time many variations in hardening and tempering treatment of various grades of 18 : 4 : 1 high speed steel were tried, including many on multiple tempering. During the last three years these results have been followed through on an extensive scale in works practice. Among the results obtained were the following:

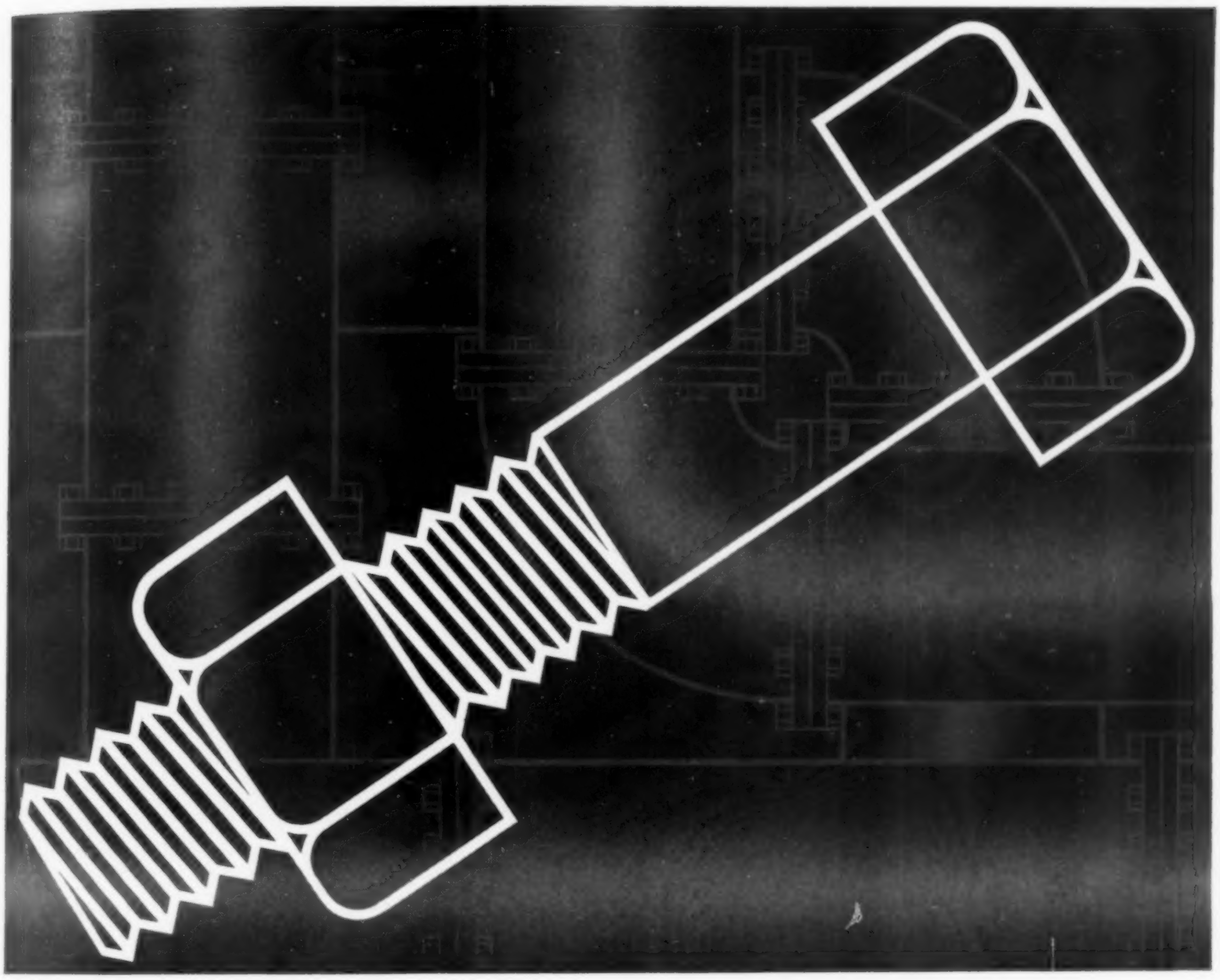
The Rockwell "C" hardness of specimens in the hardened condition before tempering did not show any considerable differences with variation of quenching temperature, but there was, however, a consistent repetition of slightly higher hardness the lower the initial quenching temperature. Practically any sort of standard tempering treatment reversed these results, that is to say, the lower the initial quenching tempering the lower the maximum hardness at any tempering temperature between 1005 and 1110° F. Representative results — tempering 168 specimens at 1040° F. for one hour — are shown alongside the "as quenched" figures in the following tabulation:

Quenched From	As Quenched	Tempered 1 Hr. at 1040° F.
2345° F.	C-65.9	C-65.4
2370	C-65.6	C-66.0
2410	C-65.1	C-66.2
2445	C-64.8	C-66.7

These results, I believe, are in agreement with much published work on the hardening and tempering of 18 : 4 : 1 steel.

On multiple tempering the typical results are as indicated by the following, cited from many experiments in this field. Twenty-four pieces were taken and six of each hardened under standardized conditions from each of four

(Continued on page 446)



"Take care of the pennies . . ."

ONE bolt is small, and comparatively inexpensive—either to buy or to make. But—bolts "in the mass" can easily represent a very considerable outlay. The saving of even a small fraction of a cent in the production cost may come to a substantial sum in the aggregate.

For example: One concern has standardized on Chrome-Moly (SAE 4140) bolts because they are easier to machine—resulting in savings on both tool expense and machining time. In addition, their improved physical properties assure better service performance.

Moly steels are cutting production costs throughout industry because they are more economical to fabricate—whether the process be heat-treating, forging, carburizing, or machining. . . . They also impart to finished products higher quality, resulting in better service.

Our free technical book, "Molybdenum," will prove useful to engineers and production heads interested in cost cutting and product improvement. Our monthly news-sheet, "The Moly Matrix," keeps readers informed on Moly developments. Consult our laboratory when ferrous problems get tough. Climax Molybdenum Company, 500 Fifth Avenue, New York City.

PRODUCERS OF FERRO-MOLYBDENUM, CALCIUM MOLYBDATE AND MOLYBDENUM TRIOXIDE

MOLY

Climax Mo-lyb-den-um Company

PERSONALS

William L. Weaver has been promoted to the position of manager of stainless castings for Ludlum Steel Co., Watervliet, N. Y.

J. C. Joublanc has been appointed chief metallurgist for the Harnischfeger Corp. of Milwaukee.

Harry R. Ansel, mechanical and structural engineer, has formed the Kor-Lok Co., manufacturers of interlocking corrugated sheet for roofing and siding. Mr. Ansel is president of the company.

H. F. Henriques and **J. J. Lincoln, Jr.** have been appointed assistant general sales managers of Air Reduction Sales Co., with headquarters in Cleveland and Pittsburgh, respectively.

W. A. Purtell has been elected president of Billings & Spencer Co., Hartford, Conn. **Frederick C. Billings,** former president, was elected chairman of the board.

Paul J. Cnare has been appointed sales representative in Wisconsin and Minnesota for The Claude B. Schneible Co. of Chicago, and **Charles C. Hermann** has been made representative in Eastern Pennsylvania.

Norman Paquin has left the Ohio Seamless Tube Co., where he was mechanical engineer, to join the Weatherhead Co., Cleveland, as research engineer.

James G. Marshall, general superintendent of the Niagara and Welland plants of Union Carbide Co. and Electro Metallurgical Co., has been awarded the Jacob F. Schoellkopf Medal for 1937 of the American Chemical Society, in recognition of his contributions to the calcium carbide and ferro-alloy industry.

N. B. Gilliland has been appointed to the sales engineering staff of The Lincoln Electric Co. in the Detroit office.

Lee P. Tolman is now employed in the Mechanical Engineering Department of the Carnegie-Illinois Steel Corp., Youngstown district.

James Allison, field service metallurgist for the Union Drawn Steel Co. in New York and New England, has been made factory manager of Billings & Spencer Co.

W. D. Coolidge and **Irving Langmuir,** director and associate director respectively of the Research Laboratory, General Electric Co., are the recipients of two of the John Scott 1937 awards of the City of Philadelphia, for outstanding improvements in X-ray tubes and incandescent lamps.

J. A. Dwyer, manager of the Philadelphia branch of Crane Co., has become district manager of all Crane branches in the eastern territory.

PERSONALS

Robert W. Schlumpf, metallurgical engineer, Hughes Tool Co., has been elected chairman of a third new Chapter in Texas. **C. H. Shapiro,** metallurgist, Reed Roller Bit Co., is vice-chairman and **Charles F. Lewis,** metallurgical engineer, the Midvale Co., is secretary-treasurer.

E. O. Mattocks is leaving American Gas Association Research Laboratory, Cleveland, to become industrial engineer for Phillips Petroleum Co., Philgas Division, in the New York and New Jersey region.

C. W. Heppenstall, president and treasurer of the Heppenstall Co., Pittsburgh, was the guest of honor at a dinner recently given by his employees in celebration of his 44 years of service with the company.

Frank J. Enright, advertising manager for **Metal Progress** since its beginning in 1930, has joined the A. F. Holden Co., New Haven, Conn., as director of sales and advertising. This announcement is made with the keenest regret, for his steady enthusiasm and his sound publishing judgment have been invaluable in maintaining a high quality in **Metal Progress.**

E. E. Thum, Editor

Gilbert S. Schaller, associate professor of mechanical engineering, University of Washington, was elected chairman of the newly formed Puget Sound Chapter. **Monte E. Parker,** Seattle Vocational School, was made secretary-treasurer.

Sam H. Graf, professor of mechanical engineering and director of engineering research, Oregon State College, is chairman of the new Oregon Chapter; **Warren J. Ulrich,** manager, Pacific Machinery and Tool Steel Co., is vice-chairman; and **Norton L. Peck,** Columbia Steel Co., is secretary-treasurer.

Bruce B. Wallace has joined the staff, in Los Angeles, of The Foxboro Co. as sales engineer.

S. F. Keener, president, Salem Engineering Co., Salem, Ohio, is spending much of his time in London, England, where an office of the Salem Engineering Co. was recently opened.

POLISHING TIN

(Starts on page 395) when polished on a rotating pad quickly renders the pad gritty. During etching, Wood's metal is usually attacked first.

Simple equipment and procedure for mounting in bakelite have been frequently described — for instance, METAL PROGRESS, November 1933, page 33, and June 1936, page 74. Mountings made under pressure at 325 to 350° F. provide an exceedingly close joint between the bakelite and the specimen, with no subsequent cracking on aging. The high temperature and pressure required, while not seriously disadvantageous for some of the harder metals and alloys, are serious drawbacks in the case of tin and tin alloys. These may be removed by using the bakelite resin in its liquid stage (first stage of polymerization) and hardening it by an acid solution at a much lower temperature. The main drawback to this plan is the presence of acid, but this does not exceed about 2.5% and for tin and tin alloys its presence has not proved objectionable.

The acid-hardening solution, as supplied by the manufacturers, contains 25% of mixed acids, organic and sulphuric; 10 cc. of this solution is added to 100 cc. of bakelite resin and stirred. The mixture is then poured into the mold and the specimen put in, and heated at 110° F. for about half an hour, when the bakelite resin begins to harden and to turn from gray to pinkish-white. It is then preferably heated at 140° F. for 1½ hr., when it sets hard.

Measurement of the required quantity of resin can be facilitated by warming it before pouring into a measuring cylinder, thus rendering it less viscous. After the warm resin has been transferred to the mixing vessel it should be allowed to become cold before adding the hardener, as the heat generated on mixing may cause the reaction to develop rapidly. If this happens, the bakelite begins to bubble and harden before the mixing is completed.

Bubbling and rapid hardening may also take place if too high a temperature is applied when setting the resin. Hence the desirability of using the lower temperature for a preliminary period and then, when the resin is sufficiently hardened, raising the temperature to about 140° F. The amount of acid to be added is critical, as the heat produced by excess of

acid accelerates the reaction and causes bubbles to form and spoil the mold.

If time permits, a safe procedure is to warm the mold containing the resin slightly to start the setting, and then allow this to continue to completion at room temperature, which takes about 24 hr.

Split brass tubing, 1¼ in. diameter, 1¼ in. long, makes a good mold. Assemble the halves on a glass plate and build a dam around the base with plasticine.

After the specimens have been mounted, they are cut through with the hacksaw and filed in the usual way. They are then polished by removing the file marks on No. 0 emery paper, passing to 1.M., then 1.F., and finishing on 00. It has been found that Huberts' 0 emery paper can be dispensed with. Where it is essential to polish finally by hand, time may sometimes be saved if the specimen is initially taken further on 000 or even 0000 emery paper. (These last papers should first be rubbed with a piece of harder metal to remove any upstanding particles which, despite the greatest care on the part of the makers, are sometimes found on them.)

The scratches from the last emery paper are removed by machine-polishing on selvyt cloth impregnated with heavy magnesium oxide, or by hand-polishing on a selvyt pad, using a commercial metal polish. There are still particles of abrasive left in the surface and frequently pad scratches; these are removed and an exceedingly fine micro-polish obtained by a short hand polish on a prepared selvyt cloth stretched on a piece of hard wood. The preparation of the cloth consists in soaking its surface with benzene and rubbing into its texture specially prepared alumina. During operation it is lubricated with distilled water. The benzene acts as a cleaner and prevents film formation on the surface of the metal, while it also keeps the surface free from abrasive particles. Light rubbing with very little powder on the cloth gives the best results.

The success of the above procedure is largely dependent on the method of preparation of the alumina. This is carried out as follows: Ammonium alum of analytical reagent purity is gently heated to remove the water of crystallization, and is then calcined for 6 or 8 hr. at 1825° F. Care is taken to keep the alumina free from grit, and for calcining a fused silica or porcelain container is preferred.

(Etching solutions are listed in Ⓜ Metals Handbook, 1936 Edition, page 1318.)

FLAKES IN INGOTS

(Continued from page 379)

at the edge of the cavity, where the radius of curvature is very small. In this way, hair cracks or flakes may enlarge with minute cavities as centers, but as the volume of these cavities increases, the pressure within them diminishes, so that the cracks or flakes cannot grow beyond a certain small volume. This explains how a number of small flakes can be scattered throughout steel ingots.

Of course, hydrogen in molten steel will usually be less than saturation. Various analysts find amounts in solid steel ranging from 0.001 to 0.0001%; hence if the volume of the cavity is on the order of 0.01 cu.mm., the tangential or breaking stress due to hydrogen becomes respectively 130,000 psi. to 13,000 psi. So it is difficult to conclude that the pressure of hydrogen gas always causes flake formation.

It is to be emphasized that flakes are produced only by the action of stress induced in the material. The study of the cause of formation of flakes is therefore nothing but the investigation into the nature of stress existing in steel ingots. The principal stresses induced in the material during cooling are: (1) The stress caused by the pressure of hydrogen gas, (2) thermal stress, and (3) transformation stress. The thermal stress arises from the difference of temperatures between the inner and outer portions of the ingot and so depends on the dimensions as well as on the rate of cooling. The transformation stress is also attributed to the time difference of the occurrence of transformation in the outer and inner portions of the ingot and so depends also on its dimension and on the rate of cooling; the last two stresses always take place superposed one upon the other.

In the case of a 16-in. sphere, one of the present writers has obtained theoretically the stress distribution along its radius, in the course of cooling, on the assumption that steel is perfectly elastico-viscous when its temperature is higher than a certain threshold value, and that it becomes perfectly elastic below this value. He has also found that the stress distribution is greatly affected by the transformation point relative to the first temperature at which steel is assumed to become perfectly elastic during cooling.

It is often stated that carbon steel is less liable to flakes than chromium steels; one of the causes is that the $Ar_{1,3}$ transformation in the alloy steels occurs at a lower temperature than it does in carbon steels, in fact, after the steel passes from plastic to perfectly elastic condition.

The amount of hydrogen escaping from an ingot during slow cooling is calculated, and from

the values it is concluded that this is a prime reason why small ingots are less susceptible to flake formation than large ones; the thermal and transformation stresses are also less.

Inclusions favor flake formation because their coefficients of expansion are different from steel, and hence cause minute inclusions for gas to collect in. The bottom of an ingot is less susceptible because it generally is cleaner and under less internal stress. Large reductions during forging are desirable because they squeeze out some hydrogen and eliminate weak points. High temperature melting and low temperature casting makes for a low hydrogen content; prolonged annealing makes steel homogeneous; slow cooling reduces thermal and transformation stresses. All these reduce flake formation.

Lastly the present writers' view regarding the relation between the flakes and the so-called "white spots" is that flakes are usually at first formed at comparatively high temperatures by the combined action of the stresses above mentioned, some portions within them remaining unbroken; at lower temperatures these portions are broken by the pressure of hydrogen gas, showing a fresh, fine-grained surface. This is similar to the relation between the peripheral portion and the central cup of the fracture in a tensile test — that is, flakes correspond to the periphery and the white spots to the cup.

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A Silvery White Plating Base
SEYMOUR NICKEL SILVER
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SEYMOUR NICKEL SILVER
For Non-Corrosive Springs
SEYMOUR
SEYMOUR PHOSPHOR BRONZE
For Friction Discs
SEYMOUR PHOSPHOR BRONZE
For Fatigue-Resistant Springs
SEYMOUR PHOSPHOR BRONZE
For Resilient Flat Springs
SEYMOUR PHOSPHOR BRONZE
For Non-Corrosive Turnings
SEYMOUR PHOSPHOR BRONZE
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